COMPARISON OF VARIANCE-TO-MEAN RATIO METHODS

FOR REPARABLES INVENTORY MANAGEMENT

THESIS

Lisa J. Mahon, Captain, USAF

AFIT/GLM/ENS/06-07

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Lisa J. Mahon, BS

Captain, USAF

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Lisa J. Mahon, BS

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Approved:

_____//SIGNED//_____   ___7 APR 06___
Bradley E. Anderson, Major, Ph.D., USAF (Chairman)   Date

_____//SIGNED//_____   ___7 APR 06___
Martha C. Cooper, Ph.D., Ohio State University (Member)   Date

AFIT/GLM/ENS/06-07

Abstract

In an effort to improve aircraft availability, this research compared the efficiency of ten methods of determining variance-to-mean ratios (VTMRs, VMRs, V/Ms) for repairable, spare aircraft parts known as reparables. These methods are base pipeline quantity, Hill-Stevens (220 LRUs), a variation of Hill-Stevens (10 1s), Hill-Stevens (230 LRUs), the Sherbrooke, a variation of Sherbrooke (10 1s), historical data, a new regression function, variance-to-mean ratio equals 1.00 or variance-to-mean ratio equals 1.01. Using VTMRs derived from quarterly organizational intermediate maintenance (OIM) demands for line-replaceable units (LRUs) from the D200A Secondary Item Requirement System (SIRS) databases in aircraft sustainability model scenarios and Excel spreadsheet simulation, this research concluded the VTMRs have an impact on aircraft availability and the cost of inventory.

Acknowledgments

Lisa J. Mahon

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I. Introduction

Background

The United States Air Force (USAF) managed almost $24 billion worth of aircraft reparables in fiscal year (FY) 2002 (Blazer and others, 2002). Efficient stockage levels of these major components are necessary for an effective, operational Air Force and are the responsibility of the Air Force Materiel Command (AFMC). Since stockage levels in the USAF supply system have been determined by the same variance-to-mean ratio (VTMR, VMR, V/M) method for over 30 years, one can understand why the Management Sciences Division of the Plans and Programs Directorate, Headquarters Air Force Materiel Command (HQ AFMC/A8S) is sponsoring this research. They are, and have been, very interested in variance-to-mean ratios for years because efficiency and annual budgets are sensitive to VTMRs.

For the purpose of this research, the definition for reparables is recoverable, usually expensive, spare aircraft parts. Recoverable parts are repaired instead of discarded when they fail. Reparables are also called spares, as in spare parts. A list of reparables includes major components such as avionics units, brake assemblies, engine fuel controls, vertical stabilizers and would exclude minor components such as bolts, nuts and screws.

In statistics, the variance, σ^2, combines all values in a data set to produce a measure of spread or statistical dispersion. The variance and standard deviation (the

square root of the variance) are the most commonly used measures for the spread of a sample. In arithmetic terms, the variance is defined as equal to the average of the square of the distance of each data point from the mean. In the supply world, the variance is an "estimate of the degree that actual demands might be dispersed about the mean" (Stevens and Hill, 1973).

The mean, μ, is probably the most often used descriptive statistic. The mean is defined as the measure of central tendency or simply stated, the average value of a data set. In the supply world, the mean is an "estimate of expected demands over some time period" (Stevens and Hill, 1973).

Additionally, in statistics, the variance-to-mean ratio (VTMR, VMR, V/M) is a measure of the dispersion of a probability distribution. In arithmetic terms, it is equal to the ratio of the variance to the mean:

$$VTMR = \frac{\sigma^2}{\mu} \qquad (1)$$

where *VTMR* is *variance-to-mean ratio*, σ^2 is *variance*, and μ is *mean*.

Three relevant variance-to-mean ratios and their values are: (1.) The Poisson distribution has equal variance and mean, giving it a VTMR $= 1$. (2.) The negative binomial distribution has a VTMR > 1. (3.) The binomial distribution has a VTMR < 1.

The first relevant variance-to-mean ratio the Poisson distribution, is statistically used to model the number of events occurring within a given time interval. For this reason, the Poisson distribution is used in this research as a validation tool for the simulation spreadsheet that randomly distributes the quarterly demand over 90 days.

In Figure 1, the simulated distribution of daily demands, sim p(x), is compared to the

Poisson distribution, Poisson (x).
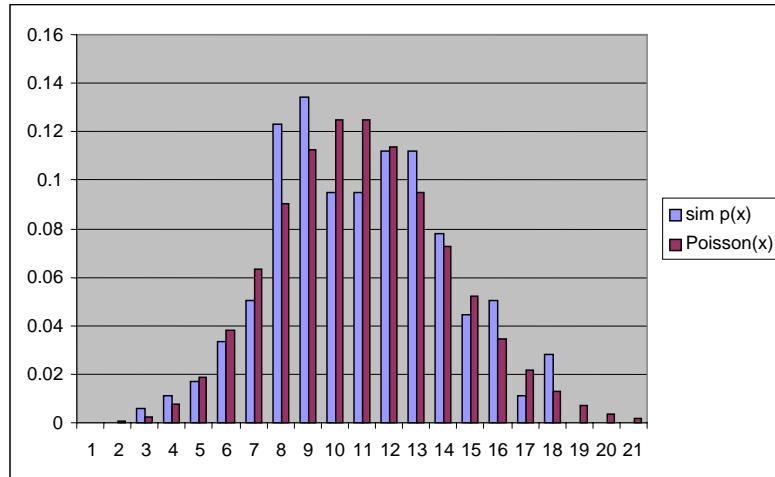
Figure 1. Comparison of Simulated Distribution and Poisson Distribution

This comparison was used as a validation tool for the simulation spreadsheet because in

inventory theory the standard assumption is VTMR = 1 meaning the variance and mean

are equal. Furthermore, Figure 1 allows visual evaluation of the fit of the two

distributions. Additionally, this research will evaluate the Poisson distribution,

VTMR = 1, as an alternative for determining stockage levels in the USAF supply system.

The second relevant variance-to-mean ratio, the negative binomial distribution,

describes the unpredictability often observed with reparables' pipeline quantities having

high quarterly demands. This unpredictability is due to variation around a known mean

and ambiguities of the calculated mean (Waters, 2005). Thus, the negative binomial

distribution is useful in this research for modeling a reparable such as a line-replaceable

unit (LRU) 014632311. Its variance exceeds its mean or, stated in another way, LRU

014632311 has a VTMR > 1. Equally important are those LRUs with erratic demand

time series. A compound negative binomial distribution models these LRUs the best. In fact, when the erratic demand time series has a significant probability of zero demand in any period, a power approximation (developed by Ehrhardt in 1976) yields lower expected total costs (Klincewicz, 1976). Specifically, John Klincewicz's simulation study used a negative binomial distribution and a compound negative binomial distribution to model an overall variance-to-mean ratio equal to nine, VTMR = 9 (Klincewicz, 1976).

The third relevant variance-to-mean ratio (VTMR, VMR, V/M), the binomial distribution, has a variance-to-mean ratio less than one, VTMR < 1. The binomial distribution is not used in this research because the Aircraft Sustainment Model (ASM) will not use a variance-to-mean ratio less than one. The ASM computer software used in the comparison process of different methods to calculate VTMR prevents a variance-to-mean ratio of less than one.

In short, the supply world uses the variance-to-mean ratio (VTMR, VMR, V/M) to derive parameters necessary for computing the negative binomial distribution used to calculate expected backorders. A backorder is an unfilled demand on supply. A typical backorder is created when a maintenance person needs a part from base supply and is subsequently informed the part is not in stock. Expected backorders are the average number of backorders over a period of time, or more specifically, the expected number of backorders at a random point in time. Most important, a line-replaceable unit (LRU) backorder at a base means a part is missing from an airplane, the airplane cannot fly and

is not mission capable. Thus, VTMRs are very important to the Air Force, HQ AFMC/A8S and the rest of the USAF supply world.

As mentioned above, the USAF has used the Hill-Stevens method for estimating a component's VTMR for over 30 years. An improved VTMR method yielding a higher availability and/or lower costs may exist.

Specific Problem

The one-size-fits-all method of R.J. Stevens and J.M. Hill prescribed in the early 1970s is still used in USAF supply models and systems today. VTMR affects all three levels of supply: deployment level (Readiness Spares Packages) via the Aircraft Sustainment Model (ASM), base level via Readiness Based Leveling (RBL) and depot level via Execution and Prioritization of Repair Support System (EXPRESS). Additionally, the Aircraft Availability Model (AAM) along with the RBL is a peacetime stock level computation system sensitive to assigned values of variance-to-mean ratios.

Equally important, the current VTMR calculation method has many potential weaknesses. For example, R.J. Stevens' and J.M. Hill's traditional approach of modeling demand for AFMC reparables uses a worldwide mean demand instead of base-level mean demand rates for each master stock number. These means are estimated in a straightforward way, item by item, using an eight-quarter moving average and ignores conventional forecasting theory of weighting more recent demand data heavier than older data. Another example of a weakness is the current VTMR method does not attempt to examine observed pipeline variance or take into account demand rate and resupply time

interaction. The US Air Force estimates pipeline variance for reparable items in the Aircraft Availability Model (AAM) and Readiness Based Leveling (RBL). Consequently, other methods may improve the accuracy of VTMR.

Research Question

Variance-to-mean ratio (VTMR, VMR, V/M) makes a difference because of the role it plays in determining stockage levels, budget allocation and ultimately aircraft availability. Thus, the following specific research question was considered in an effort to seek a possible alternative to the current USAF policy for stocking reparables:

Will the base pipeline quantity, Hill-Stevens (220 LRUs), a variation of Hill-Stevens (10 1s), Hill-Stevens (230 LRUs), the Sherbrooke, a variation of Sherbrooke (10 1s), historical data, a new regression function, variance-to-mean ratio equals 1.00 or variance-to-mean ratio equals 1.01, yield the highest aircraft availability given the same reparables budget?

Research Focus

The goal of this thesis is to provide insight into the sensitivity of the variance-to-mean ratio (VTMR, VMR, V/M) and to determine the biggest bang for the buck when comparing dollars spent and aircraft availability percentages.

Investigative Questions

The following specific investigative questions were developed to support the comparisons of the variance-to-mean ratios for the ten methods:

1. Are the calculated VTMRs from the ten methods comparable?

2. Is there a relationship between the means and VTMRs?

3. Do the results provided by the Aircraft Sustainment Model (ASM) permit an adequate comparison of the methods?

4. Will an Excel simulation spreadsheet using demands for fiscal year (FY) 2003 to calculate aircraft availability add more value than if FY 2003 demands were not used for the evaluation?

5. Which method of estimating VTMR yields the lowest total cost and the highest aircraft availability, the biggest bang for the buck?

Methodology

The first investigative question was answered by a qualitative comparison of the VTMR values achieved from the ten methods using the same set of data. Any conflicting or extreme values of the individual reparables will be highlighted and explained.

A scatter plot of the VTMR verses the mean for the historical data was used to answer the second investigative question. Comments on any observed relationships found were also included in the answer.

The third investigative question was answered by comparing the output files of the Aircraft Sustainment Model (ASM) are compared from the different runs. These

output files were examined for consistency across the ten alternatives. Additionally, HQ AFMC/A8S personnel validated a sample of the output files by running the same parameters in their ASM version.

The comparison of the aircraft availability achieved with ASM and the aircraft availability achieved with the simulation spreadsheet model using FY 2003 demands was employed to answer the fourth investigative question. This comparison should add value to the results of this research by providing a secondary and realistic assessment of the ten methods.

The fifth investigative question was answered with an assessment of the percentage of aircraft availability attained with the simulation spreadsheet for each method. It may be necessary to average the aircraft availability for each airframe type to determine the system VTMR method that yields the biggest bang for the buck.

Assumptions/Limitations

Data and sample size used for this research differs from the Hill-Stevens and Sherbrooke studies.   Their 33-year old and 22 year-old data are no longer available and may not represent the characteristics of today's USAF inventory. Software parameter constraints such as a the VTMR floor and cap of 1.0 and 7.0, respectively, in the ASM tool and demand data rounding in the Excel spreadsheet simulations represent other assumptions and limitations. Additionally, several subject group master (SGM) line-replaceable units (LRUs) in the source data had multiple records. These records identified different item quantity per application (IQPA). In these instances, the IQPA

with the highest value was selected. Another limitation could be the Excel spreadsheet simulation used to determine backorders does not consider a single aircraft could have multiple backorders. The Excel spreadsheet simulation assumes one backorder per aircraft. Lastly, the impact of LRU size and cube on inventory storage space is not considered in this research.

Implications

If implemented, the results of this research could alter managerial decisions on stockage levels for reparables in the United States Air Force (USAF), other branches of the United States Military, and even those in the civilian world. It may show the Hill-Stevens method of determining variance-to-mean ratio is not the most efficient and a change to a business policy the USAF supply world has used for over 30 years should be forthcoming. The chain in Figure 2 visually shows how this transformation would unfurl.

VTMR → Negative Binomial → Probability → Marginal Analysis → Stockage Level

Figure 2. Variance-To-Mean Ratio (VTMR) Initiated Chain of Action

Preview

This study will provide insight into the sensitivity and importance of the variance-to-mean ratio and the effect it has on stockage levels of reparables and aircraft availability in the United States Air Force.

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II. Literature Review

Chapter Overview

This chapter provides an overview of significant previous studies that used variance-to-mean ratios to model the demand for recoverable, spare aircraft parts known as reparables. Although VTMR and VMR are the two most commonly used acronyms for variance-to-mean ratio today, V/M was the shorthand for variance-to-mean ratio in printed works of the 1960s and 1970s. This chapter focuses heavily on the works of R.J. Stevens, J.M. Hill, and Craig C. Sherbrooke because these are the big names in the United States Air Force (USAF) supply world when it comes to VTMRs and reparables. The works of these three men provide the basis for this research. Does the prevailing method prescribed by the Stevens-Hill Team, or the challenger, solo Sherbrooke, have the best method for determining the variance-to-mean ratios for reparables? Or, historical data only, a new regression function, or simply variance-to-mean ratios equal one (VTMR = 1) or 1.01 (VTMR = 1.01) prove to be the most efficient way of determining the VTMRs for reparables?

Most Air Force Institute of Technology literature reviews are not complete without a reference to a RAND study and this one is no exception. Details on a RAND Corporation study using F-15 line-replaceable units (LRUs) and shop-replaceable units (SRUs) are included in this chapter as well. Lastly, this chapter provides other related topics by lesser-known authors.

Description

In March 1973, R.J. Stevens and J.M. Hill published Working Paper Number 49 entitled "Estimating the Variance-to-Mean Ratio for Recoverable Items in the ALS [Advanced Logistics System] Marginal Analysis Algorithms". Marginal analysis is a microeconomics technique used to study very small changes in specific variables to determine their effect on related variables and the system as a whole. Algorithms are systematic problem-solving procedures, especially established, recursive computational procedures, used for solving a problem in a finite number of steps. In the United States Air Force (USAF) supply world, Working Paper Number 49 is referred to as the Hill-Stevens Paper. This 49-page paper was conceived and born in the Systems Studies Branch of the Headquarters, Air Force Logistics Command, Wright-Patterson AFB, Ohio, and quickly became the new standard operating procedure for determining stockage levels for reparables in the USAF supply system. The authors made quite an impact. Indeed, variance-to-mean ratios (VTMRs, VMRs, V/Ms) are used to derive the parameters necessary for computing the negative binomial distribution. The negative binomial distribution is used to calculate expected backorders and from expected backorders, aircraft availability rates are calculated. The lower the aircraft availability rate, the fewer aircraft missions are flown. Thus, VTMRs play an important role in the United States Air Force (USAF). Somehow, despite challenges from at least one ardent opponent, the Hill-Stevens method of calculating variance-to-mean ratios (VTMRs, VMRs, V/Ms) is still used today, 33 years later, based on the original data. Will this research change that?

The biggest names in the USAF supply community for to determining demands for reparable are R.J. Stevens and J.M. Hill. Although Stevens and Hill definitely seem to be on top for the last thirty plus years, one has to wonder if Craig C. (C.C.) Sherbrooke, the ardent opponent mentioned in the previous paragraph, helped get Stevens and Hill there. Sherbrooke's November 1966 RAND Memorandum entitled "Metric: A Multi-Echelon Technique for Recoverable Item Control", is referenced in the Hill-Stevens legendary Working Paper Number 49. As an interesting side note, C.C. Sherbrooke does not call the outcome of the R.J. Stevens' and J.M. Hill's Working Paper Number 49 the Hill-Stevens method, opting instead for the moniker of the Stevens-Hill estimation (Sherbrooke, 2004). Sherbrooke is not alone in his less than favorable review of the Hill-Stevens' variance-to-mean ratio (VTMR, VMR, V/M) method. It could conceivably be said Sherbrook is joined by his 1988 co-author of "The Nature of the Aircraft Component Failure Process: A Working Note", F.M. Slay. In the note page of the Overview slide of his presentation at CRACKPOTS, entitled "The Origins of VMR", Slay typed, "I have a lot of heartburn over how people use VMRs, even how they use the word 'VMR'. And I'd like to thank the academy for this opportunity to speak on behalf of misunderstood VMRs everywhere (Slay, 2004)." "CRACKPOTS is an informal group of computation requirements subject experts from LMI, AF, and Northrup Gruman that meet quarterly to discuss logistics and operations research issues (Burnworth, 2006)." Two slides later, again in the note page of the same PowerPoint, and perhaps once more with a slant, Slay typed, "Here's a little history of the Hill-Stevens (or, as the original paper is actually titled, Stevens-Hill). They went to great effort to deal with the

limitations of only 16 data points for each NSN (Slay, 2004)." Indeed, the stage is set for a competition to determine who has the best VTMR method. Let the literature review begin.

Before Hill-Stevens

Before R.J. Stevens and J.M. Hill published Working Paper Number 49, the mean was "computed for each item using several usage factors and inputed [sic] to the algorithms" (Stevens and Hill, 1973) and instead of computing a variance-to-mean ratio (VTMR, VMR, V/M) the algorithms used a V/M of 1.01 for all items. The justification for the 1.01 was the assumption that all reparables' demands fit a Simple Poisson Probability distribution (Stevens and Hill, 1973). Although there was a consensus the standard 1.01 value was not the best method for the V/M, it was thought of as a safe standard (Stevens and Hill, 1973). In other words, it would neither greatly affect the marginal analysis algorithms effectiveness nor cause misallocation of resources. The later, of course, was very undesirable (Stevens and Hill, 1973). Stevens and Hill stated a more suitable method than the standard 1.01 would be difficult to determine. Apparently, they managed to find that suitable method and it may be difficult to improve upon since no one has succeeded in replacing it yet.

Hill-Stevens

R.J. Stevens and J.M. Hill took on the challenge of developing a better method for determining a reparables' variance-to-mean ratio (VTMR, VMR, V/M). Hill-Stevens

used V/M as their shorthand for variance-to-mean ratio in the 1960s and 1970s. Fittingly, V/M will be used when referring to research of those two decades.

The Hill-Stevens study measured a component's V/M based on its quarterly demand variance. A small sample size of 16 quarters of worldwide demands for each national stock number (NSN) is the basis of the Hill-Stevens research.

In Chapter V., The Methodology, Hill-Stevens outlines their strategic plan:

> The basic concept used in the development of the relationship between V/M and mean is based upon the premise that knowledge of an item's variance with a given demand level (mean) can be enhanced by studying the variance of items having the same demand level. This premise becomes especially useful in those individual item situations where unstable demand patters and /or insufficient number of observations exist such that the sample variance becomes an unreliable estimate for future projections. (Stevens and Hill, 1973)

Ultimately, their 1973 study proposed two alternatives to the then current standard V/M value of 1.01, a technique A (Average) and technique B (Percentage).

For their technique A, Hill-Stevens used just eight quarters of demand data, April 1969 through March 1971. At the time, this two-year period was the most recent data available. Hill-Stevens further justified their data selection:

> Only two of the four year's worth of available demand data were used because (1) under the method being proposed this seemed sufficient for making the necessary V/M ratio computations, and (2) the changeable nature of the recoverable item inventory did not seem to indicate that a longer time frame would be desirable. (Stevens and Hill, 1973)

Their first step in the quest for a better V/M method reduced the population data of NSNs from 23,841 to 16,399 (12,552 XD, 3,847 XF) by eliminating those items with over 70 % of their total demands in the first or second year. Next, keeping the XD and XF

Expendability, Recoverability, Repair Codes (ERRCs) separated, they grouped the data by number of demands. After analysis of scatter diagrams, they established upper boundaries on V/M values to eliminate unstable demands. In this case, an unstable demand is one with most of its demands in one or two quarters. Then they regrouped the items into demand classes. These demand classes were established by number of items and change in variance-to-mean ratios (VTMRs, VMRs, V/Ms). Thus, the final outcome of their data scrubbing resulted in 59 XD and 17 XF means, each with corresponding V/Ms.

Now, they needed to find a mathematical relationship between their means and V/Ms. Subsequently, they input these 76 data pairs into a Least Squares Curve Fitting Program available on the CREATE Computer System (Stevens and Hill, 1973). They evaluated six possible functional relationships (linear, exponential, power function and three hyperbolic) with the curve fitting program. Using the index of determination as their guide, they discovered the best fitting power function:

$$Y = A * X^B \qquad (2)$$

where Y is *variance-to-mean ratio*, X is *mean*, and A and B are *parameter values*

The estimates for A and B in the power function were derived from a regression on the logarithms of the data (Sherbrooke, 1984). In brief, the above is Hill-Stevens' technique A.

Hill-Stevens' technique B is an extension of their technique A. In other words, technique B used 16 quarters of demand data, which produced two, two-year periods. Again, the number of demands within the respective ERRCs were used to group the data.

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After data scrubbing this time, the outcome also resulted in two sets of 59 XD and 17 XF means, each with corresponding V/Ms. Next, these two sets of data pairs were reduced to one set with the help of a demand transition matrix. The demand transition matrix traced the group the item was in during the first two-year period to the group it was in during the second two-year period (Stevens and Hill 1973). Using the information from the demand transition matrix and the mean and V/M calculated with technique A, new means and V/Ms were created for the one remaining set of 76 data pairs. These new data pairs were input into the same Least Squares Curve Fitting Program. Likewise, using the index of determination as their guide, they discovered the power function $Y=A*X^B$ fit best. In words, the power function implies as the mean increases, the V/M also increases, but at a decreasing rate (Stevens and Hill 1973). Consequently, both Hill-Stevens technique A and technique B results were essentially the same and support their selection of the power function $Y=A*X^B$ to calculate the V/Ms used to model the demand for reparables.

In short, the alternatives they tested were based on a system concept, relied on a mean and used a power function to compute the V/M values. Furthermore, both techniques required very little additional programming and minimized additional machine time requirement, hence, providing an appropriate return on investment of time and money. Lastly, the Hill-Stevens research found empirically the V/M does not align with the standard value of 1.01.

Accordingly, HQ AFMC implemented the Hill-Stevens method in June 1987 and still uses it today. Over time, Hill-Stevens' original power function formula was updated with Greek letter μ to symbolize the expected value. This new version of the formula

$VTMR = A\mu^B$ invokes Palm's Theorem which assumes a steady-state Poisson failure arrival process (Crawford, 1981) can be applied to pipeline reparable items. Thus, HQ AFMC uses this formula to compute pipeline variance from the pipeline mean. The USAF estimates pipeline variance for reparable items in the Aircraft Availability Model (AAM) and the Readiness Based Leveling (RBL) peacetime stock-level computation systems. As a result, the current version of the Hill-Stevens formula is:

$$VTMR = 1.132477 * PipelineQuantity \wedge .3407513 \quad (3)$$

where

VTMR is *variance-to-mean ratio*

PipelineQuantity is the *mean pipeline quantity*

and is used in the D200 system to determine the spare parts requirements for the Air Force for all aircraft reparables (Niklas, 2005). Sometime in the past, lower and upper limits were set for the calculated VTMRs. The VTMR values were limited to greater than or equal to 1.01 and less than or equal to 5, *$1.01 \leq VTMR \leq 5$* (Niklas, 2005). While the Hill-Stevens method for calculating V/Ms was slightly modified over the years, as indicated above, it remains the prevailing method in the USAF supply world.

Sherbrooke

Craig C. Sherbrooke is a prolific publisher in the field of inventory and offers a compelling argument for an alternative to the Hill-Stevens method. He has over 40 years

of experience in the profession and has worked for the Logistics Management Institute (LMI), the RAND Corporation and under contract in support of Air Force Logistics Command. Since 1963, his credits include at least twelve solo and five co-authored articles or books (Sherbrooke, 2004). A self-employed Sherbrooke took matters into his own hands on 27 January 1984 when he published his "Estimation of the Variance-To-Mean Ratio for AFLC Recoverable Items: Final Report".

"Estimation of the Variance-To-Mean Ratio for AFLC Recoverable Items: Final Report" is Sherbrooke's biggest campaign to replace the Hill-Stevens method. In it, he states:

> The Air Force uses the mean demand for an item to predict the variance-to-mean (V/M) ratio for recoverable item requirement computations. The objective of this research is to find a better prediction technique. It is shown that current techniques for predicting the V/M from the mean can be improved using a more appropriate model and estimation method. (Sherbrooke, 1984)

Clearly he is referring to the Hill-Stevens method since it is the "current techniques for predicting the V/M". Sherbrooke starts his offensive on the Hill-Stevens method by faulting their regressions. He points out the Hill-Stevens' regressions were not weighted by the number of items in each demand level (Sherbrooke, 1984). Since the objective is to fit the population of items as well as possible, Sherbrooke shows regressions weighted by the number of items in each demand class appears to be more appropriate. See Table 1. Next, Sherbrooke suggests his own equation. He presents Stevens and Hill's as a "power curve relation of the form":

$$V/M = AM^B \qquad (4)$$

where

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V/M is the *variance-to-mean*

M is the *mean demand*

A, B are "*parameter determined by using regression on the logarithms of the data for item means and V/M's*" (Sherbrooke, 1984).

Then, Sherbrooke introduces his own equation to support his position. It is:

$$V/M \ = 1 + AM^B \qquad (5)$$

where *V/M* is *variance-to-mean ratio*, *M* is *mean*, and *A* and *B* are *parameters*

Sherbrooke says this is a "more reasonable model, because the V/M shouldn't really go to zero as M gets small as implied by" Equation 4 (Sherbrooke, 1984). The Hill-Stevens technique A had two V/Ms less than one. Similarly, Sherbrooke did linear regression on the logarithms of the data to estimate the parameters. The only difference is he used V/M-1 instead of V/M as his dependent variable. Shebrooke does concede that both equations have the "nice property" of a functional form that allows the mean to be defined over any time period (Sherbrooke, 1984). He uses this "nice property" to analyze the Hill-Stevens method.

For comparison purposes, Sherbrooke performed the same steps as Hill-Stevens using different data and took the opportunity to use the "nice property" to select a single annual mean verses the two-year mean used by Hill-Stevens. Besides being over ten years old and unavailable, the Hill-Stevens' data may not have had the characteristics of 1984 Air Force Logistics Command (AFLC) inventory items. Therefore, Sherbrooke requested and received a random sample of recoverable items from the AFLC. The 1,030 items he received had "world-wide base level demands (Sherbrooke, 1984)" in every

quarter from June 1979 to May 1983. Now, with this data in hand, he began his comparison in an attempt to find a better method of calculating variance-to-mean ratios for reparables.

Table 1 lists the methods and results of Sherbrooke's comparison.

Table 1. Sherbrooke's Comparison Results

Case	Technique	Weighted	Equation	A	B	r^2
1	A	No	4	.7072	.3403	.913
2	A	Yes	4	.8182	.3045	.874
3	B	No	4	.7584	.3125	.896
4	B	Yes	4	.8863	.2745	.845
5	B	No	5	.0906	.6839	.723
6	B	Yes	5	.0732	.7244	.610
6NR	B	Yes	5	.1478	.5640	.998

Cases 1 and 3 are the replicas of Hill-Stevens Techniques A and B, respectively. The other five cases listed are variations of Hill-Stevens Techniques A and B. In Cases 2 and 4, the regression is weighted by the number of items in each demand class. Cases 5, 6, and 6 Non-Regression (6NR) replaces the Hill-Stevens' Equation with the Sherbrooke's Equation. The last column in Table 1, r^2, is the actual percent of variance explained by the equation when estimating parameters A and B. Not surprisingly, the r^2 maximizing iterative procedure of case 6NR has the highest r^2, .998. Thus, Sherbrooke concludes Case 6NR is a better method of calculating variance-to-mean ratios for reparables.

In the same report, Shebrooke states the Hill-Stevens method will tend to overstate the V/Ms because it did not use program data such as flying hours (Sherbrooke, 1984). Therefore, this research designates the following equations from Appendix A of the same report as the methodology for the Sherbrooke method:

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$$X = \frac{\sum_{n=1}^{N} x(n)}{\sum_{n=1}^{N} f(n)} \qquad (6)$$

$$V/M = \frac{1}{X(N-1)} \sum_{n=1}^{N} f(n) \left[\frac{x(n)]}{f(n) - X} \right]^2 \qquad (7)$$

where

X is the *mean demand per flying hour*

V/M is the *variance-to-mean ratio*

N is the *number of periods*

x(n) is the *demand during period n*

f(n) is the *flying hours*

This time Sherbrooke's data set consists of 215 first level units (FLUs) he obtained from Abell et. al's 1982 study (Sherbrooke, 1984). FLU is a predecessor name for a LRU. His data source supplied F-16A and F-16B item demands and flying hours for five six-month periods. Chapter 4 of this research details the results of the Hill-Stevens and Sherbrooke methods using the same data.

Sherbrooke also suggests his method of calculating V/M for individual items is superior to the Hill-Stevens procedure which categorizes items in demand class groups and then finds a mean for the group. Lastly, Sherbrooke asserts his method "should lead to better allocations of budget and higher availabilities from a specific budget"

(Sherbrooke, 1984). Again, Chapter 4 of this research will either support this statement or not.

Another Sherbrooke accomplishment is his development of a spares requirement estimation method called variable safety level (VSL). He derived VSL directly from the Multi-Echelon Technique for Recoverable Inventory Control (METRIC) Model (Adams and others, 1993). In 1975, the Air Force Logistics Command (AFLC) implemented the VSL algorithm and used it as the principal ingredient in safety stock computation for many years. The Aircraft Availability Model (AAM) has since replaced VSL.

In conclusion, after more than forty years, C.C. Sherbrooke is still pursuing many important issues in supply stockage policy with his books and presentations, including United States Air Force (USAF) adoption of his method for calculating VTMRs.   It has been said, Sherbrooke and a RAND colleague, J.G. Feeney, "… dealt effectively with virtually every demand problem raised by those whose work preceded theirs (Adams and others, 1993)." Certainly, Sherbrooke and Feeney are not the only RAND researchers with expertise in the area of reparables.

RAND Corporation Study

First of all, a little history and some interesting side notes about RAND. General Henry Harley "Hap" Arnold, commander of the United States Army Air Forces (USAAF), founded Project RAND in May 1946. In May 1948, Project RAND separated from the United States Army and became an independent non-profit organization. The RAND Corporation, a recognized American think tank, initially did research and analysis

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for the United States Military only but later expanded its customer source to other governments and commercial organizations as well. Over the years RAND invented numerous analytical techniques, including dynamic programming, game theory, the Delphi method, linear programming, systems analysis, and exploratory modeling (Wikipedia, 2006). It is said RAND researchers also developed many of the principles used to build the Internet (Wikipedia, 2006). Not surprisingly, the RAND Corporation's core values of quality and objectivity, along with their mission of improving policy and decision-making was evident in their 1993 report entitled "Modeling and Forecasting the Demand for Aircraft Recoverable Spare Parts".

Chapter 3 of the above-mentioned RAND Report is of pertinent interest to this research because it detailed observations made from base-level demands for F-15C/D recoverable line-replaceable units (LRUs) and shop-replaceable units (SRUs). More precisely, the authors, John Adams, John Abell, and Karen Issacson, extracted demand data from base supply transactions initiated by the base's maintenance activities at Bitburg Air Base, Germany (Adams and others, 1993).

The authors reopened some of the demand modeling issues raised by earlier RAND researchers for their study. One such researcher was G.B. Crawford. In 1988, Crawford found items with high demand variability tend to be the problematic ones in terms of inventory system performance (Crawford, 1988). Undeniably, the driver for their study was a paying customer with concerns about ineffective combat logistics support.

The Air Force Logistics Management Agency (AFLMA), which in 1993 was called the Air Force's Logistic Management Center (LMC), at Maxwell AFB-Gunter Annex, Alabama "kindly" provided RAND with the 48-weeks' (less than a year) worth of transactional data from 973 LRUs and SRUs for the study (Adams and others, 1993). After dividing the demand data into 24 two-week periods the authors assigned the variable "j" to represent each of the 973 items. Next, they computed the mean demand rate for each item, m_j, by averaging the newly created 24 demands for every "j". Lastly, they declared the unbiased estimator of the variance divided by m_j to be the variance-to-mean ratio (VTMR), r_j. Conspicuously, the distribution of r_j had a very long tail with some extremely high VTMRs. The highest VMTR was a shocking 56.16 (Adams and others, 1993).

Four relevant conclusions from this RAND Report are: (1) Using monthly flying hours with monthly demands would not have changed the distribution of the VTMRs. (2) Items with large quantities per application (QPAs) tend to have high VTMRs. (3) Reparables' worldwide demands should not be applied directly to base-level demands as the current system does. (4) The VTMR estimator has serious measurement problems. (Adams and others, 1993). The first relevant conclusion provides the justification for not including monthly or quarterly flying hours in any method evaluated in this research except Sherbrooke's. The second relevant conclusion does not seem to apply to this research. The item used in this research with the largest QPA, LRU 013077245, has a QPA of 43, which under the historical data method only produces a VTMR of 1.0476. The third relevant conclusion is still in affect; reparables' worldwide demands are applied

directly to base-level demands in the current system and in this research. Finally, this research does not use the same VTMR estimator as the RAND study. Consequently, this research did not experience the serious measurement problems noted in the forth relevant conclusion.

Blazer and Others

Although this research does not attempt to forecast demands for reparables (a forecasting study using the ten methods evaluated in this research is suggested as further research), forecasting is important and the next logical step in the process. Thus, one relevant study involving forecasting will be discussed. Specifically, Blazer and others analyzed and developed alternative forecasting techniques for both demand averages and demand variation for Economic Order Quantity (EOQ) items. By comparing the current and alternative forecasting techniques using demand histories simulated over 50 years, they found that the original method provided as accurate an estimate of average demand as any alternative method tested. However, their study stated the current system's estimate for demand variation is inadequate. A statistical analysis of actual Air Force EOQ items' demand histories supported their conclusion that estimates of demand variation are inadequate. The current system underestimates the demand variance for over 40% of the Air Force EOQ items. (Blazer and others, 1984).

Of particular interest is Readiness Based Leveling (RBL) because its levels of worldwide requirements are computed centrally by Headquarters Air Force Materiel Command (HQ AFMC) and pushed to the users at all bases. In fact, David A. Fulk's

"Demystifying RBL" called RBL "the cornerstone of the supply system for setting recoverable parts levels in the supply system" (Fulk, 1999). In its predecessor system, the Repair Cycle Demand Level (RCDL), levels were computed locally with a relatively simple formula explained in Air Force Manual (AFM) 23-110. But since its implementation in April 1997, the RBL model has often been viewed as a black box where data goes in and levels come out and only a very few people know what goes on inside. Because of this, users often feel that RBL is more of a shove system than a push system (Fulk, 1999). Unfortunately, after this research most base-level users will still feel RBL is a shove system because it will still allocate the worldwide requirement to all bases in the same manner and they will not have read this study, making them aware of what the best method is for setting recoverable parts levels in the supply system.

Summary

This chapter provided an overview of significant previous studies done using variance-to-mean ratios (VTMRs, VMRs, V/Ms) to model the demand for reparables. The Hill-Stevens's and Sherbrooke's studies are the most important because they provide the means to carry out two-tenths of this research. Specifically, this research will recreate the exact steps taken by each method to arrive at their V/M calculations. For the first time, the pseudo rivals will be on a fair and equal battlefield. This long awaited test eliminates potential bias by using the same demand data from 230 line-replaceable units (LRUs) for the comparison. Since the ultimate objective of this research and the United States Air Force (USAF) is to find the most efficient estimator in terms of the highest

aircraft availability given a target dollar amount, seven additional methods of calculating

VTMRs will also be compared using the same demand data from the 230 LRUs.

III. Methodology

Chapter Overview

The variance-to-mean ratio (VTMR, VMR, V/M) studies of Hill-Stevens and Sherbrooke years provide the foundation for this research. However, the Hill-Stevens study was completed in 1973 and the relevant Sherbrooke study was completed in 1984. Until now, the Hill-Stevens and Sherbrooke studies were never compared using the same data.

At least eight other alternatives exist for determining stockage levels of reparable using variance-to-mean ratios (VTMRs, VMRs, V/Ms): base pipeline quantity, Hill-Stevens (10 1s) - supplemented with VTMR=1 for eliminated items, Hill-Stevens (230 LRUs), a variation of Sherbrooke (10 1s), historical data, a new regression function, variance-to-mean ratio equals 1.00 or variance-to-mean ratio equals 1.01

The purpose of this chapter is to detail the research steps used to achieve a systemic framework for obtaining unbiased results when comparing the ten above-mentioned alternatives for calculating VTMRs.

This chapter describes the methodology used for the research, including the research objectives, data selection, research design, research questions, research design implementation, significant of the research, and expected results.

Research Objective

Aircraft availability is the USAF objective when allocating funds for spare parts.

The objective of this research mirrors the USAF objective. It aims to determine if an improved method exists for calculating VTMRs in order to produce a more accurate stockage level and minimize expected backorders with the ultimate goal of achieving higher aircraft availability rates at lower costs.

Data Selection

Quantitative worldwide quarterly organizational intermediate maintenance (OIM) demands and the flying hour program data was used for this research. First quarter fiscal year 2000 through the fourth quarter of fiscal year 2003 provided 16 quarters of data for unique line-replaceable units (LRUs) on A-10A, B-2A, and F-15E weapons systems were selected. The data were sourced from the Ddb04 table of the March 2001, March 2003 and March 2005 D200A Secondary Item Requirement System (SIRS) databases.

These 16 quarters are the most recent available that provide a sufficient quantity of LRU data. The data was pulled by sub group master (SGM) which equates to the portion of the national stock number (NSN) identifying a LRU. The national item identification numbers (NIINs), the 9 digits after the federal stock class (FSC) in the NSN, used by Hill-Stevens are more difficult to pull from the databases than SGMs and include smaller component parts. The first level units (FLUs) used by Sherbrooke is just a predecessor name for a LRU. Focusing on LRUs met the scope and objective of this research in the most efficient manner. Limiting the data selection to LRUs kept the data at a manageable level and gave a better, bigger picture on items most likely to affect aircraft availability.

Although 374 LRUs were initially considered, 144 were purged. These 144 were eliminated because they lacked a positive-demand value for the holdout year of 2003 and/or their quarterly flying hour data was not complete for the entire four-year period.

In summary, the 230 LRUs, displayed by airframe type in Table 2, chosen to compare the ten methods, provided consistent, quality data points while providing the most significant impact on the results.

Table 2. Number of LRUs Per Airframe

Airframe	Number or LRUs
A-10A	33
B-2A	136
F-15E	61
Total	230

Research Design

The research design has three progressive stages. The first is to determine the values of the VTMRs for the 230 LRUs accurately for each of the ten methods. This is more difficult for some of the methods than others. The exact procedure taken to calculate the VTMRs for each method is described in the Research Design Implementation section of this chapter. A scatter plot of the VTMR verses the mean for al 230 LRUs, including comments on any observed relationships found, is the second and final step of this first stage.

The second stage of the research design focuses on the Aircraft Sustainability Model (ASM). ASM is an analytic model that optimizes the set of spare parts required to maintain a specified flying program. The Air Force developed ASM jointly with Logistics Management Institute Government Consulting Company (LMI), a not-for-profit organization and advisor of the Department of Defense (DoD). LMI claims to be "free of

commercial or political bias and dedicated to advancing government management (LMI, 2006)." Additionally, ASM is the model used by the sponsors of this research, HQ AFMC/A8S, "to answer questions and run analyses regarding both wartime and peacetime scenarios (Waters, 22 March 2006)." For the above reasons, the ASM software was used to determine the set of spare parts theoretically purchased under each of the ten methods given an airframe-specific budget.

An Excel simulation is the primary tool of the third stage. The simulation's purpose is to model the inventory of reparables for a fleet of aircraft for one year. The simulation is loaded with a set of spare parts and the number of resupply days required for each of the spare parts. In the case of this research, the spare parts are LRUs. Both the set of spare parts and the number of resupply days are obtained from the ASM output file. Actual quarterly demands for a recent previous fiscal year add realism to the simulation. The quarterly demands are randomly distributed across their respective quarter. The simulation is put into motion by a click on the apply command button and the quantitative aircraft availability percentage results. This final stage in the research design will answer the research question.

Investigative Questions

The following specific investigative questions were developed to support the comparisons of the variance-to-mean ratios for the ten methods:

1. Are the calculated VTMRs from the ten methods comparable?

2. Is there a relationship between the means and VTMRs?

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3. Do the results provided by the Aircraft Sustainment Model (ASM) permit an adequate comparison of the methods?

4. Will an Excel simulation spreadsheet using demands for fiscal year (FY) 2003 to calculate aircraft availability add more value than if FY 2003 demands were not used for the evaluation?

5. Which method of estimating VTMR yields the lowest total cost and the highest aircraft availability, the biggest bang for the buck?

Research Design Implementation

The first progressive stage of research design implementation begins with the data set of 230 LRUs. Next, the ten methods are applied to these 230 LRUs to calculate variance-to-mean ratios.

The first method is the base pipeline quantity. The spreadsheet in Appendix G along with Equation 12 were used to calculate the VTMRS for this method. This method represents the VTMRs currently used in USAF supply system

The second method is the Hill-Stevens (220 LRUs). Since Hill-Stevens technique A and technique B results were essentially the same and both supported the use of power function $Y=A*X^B$ to calculate the VTMRs, this research designated technique A as the Hill-Stevens method due to the LRU data available. Technique B requires four years worth of data and although four years of data are available for this research, only three years were used for determining VTMRs. The fourth year was set aside as holdout data

to evaluate the methods. Technique A requires only two years worth of data, so the eight quarters from the beginning of 2001 to the end of 2002 will suffice.

The Hill-Stevens method starts with the 230 LRUs. The first step consists of eliminating those items with over 70 % of their total demands in the first or second year. The second step is to group the items by their Expendability, Recoverability, Repair Codes (ERRC). Reparables have either an XD or an XF ERRC classification. All of the LRUs in this study have a "T" ERRC. A "T" ERRC is used in the D2000 system and refers to a XD reparable (Burnworth, 23 FEB 2006). If necessary, keep the XD and XF separated. The LRUs are then grouped by total number of demands. After analysis of scatter diagrams, upper boundaries on VTMR values are established to eliminate unstable demands. In this case, an unstable demand is one with most of its demands in one or two quarters. The next step is to regroup the LRUs into demand classes. These demand classes are established by number of items and change in variance-to-mean ratios. Ideally, at least 30 items should be in each demand class to meet the Central Limits Theorem (CLT) qualification of a significantly large sample. Now that the LRUs are in demand classes, a mathematical relationship between their means and VTMRs is needed. Since the Least Squares Curve Fitting Program available on the CREATE Computer System that Stevens and Hill used was not available, JMP will be used in its place. The means and VTMRs were increased to one if calculated as less than one and are entered into the first and third columns of a JMP data table for the Hill-Stevens method. The formula $Y=A*X^B$ is entered into the second column. The estimates for A and B in the power function will be derived from a regression, also done in JMP, on the logarithms of

the data. Next, JMP will fit these means and variances to the power function and generate the Fitted VTMR Formula in the fourth column. See Appendix C for screen shots of the JMP data table and fitted formula. Thus, the data in the fourth column are the VTMRs increased to one if less than one for the Hill-Stevens method.

The third method is the variation of Hill-Stevens method (10 1s). It is of interest to this research because the Hill-Stevens method started with 230 LRUs but will likely finish with less. LRUs will probably be eliminated during the first step when items with over 70 % of their total demands in the first or second year are cut. In addition, the number of LRUs that ultimately are assigned VTMRs could decrease again when upper boundaries on VTMR values are established to eliminate unstable demands. Thus, in an effort to achieve diversity in the methods, those LRUs not assigned a VTMR under the Hill-Stevens method will be assigned a VTMR of 1.00 to supplement the Hill-Stevens method and create the second alternative, a variation of Hill-Stevens method (10 1s).

 The fourth method is the Hill-Stevens (230 LRUs). For this method all 230 LRUs are assigned a VTMR calculated from the JMP values for the a and b parameters in the fitted formula $Y=a*m^b$. JMP determined $a = .287695$ and $b = .775911$. Reference Appendix C.

The fifth method is Sherbrooke method. For the Sherbrooke method the 230 LRUs, using eight quarters from the beginning of 2001 to the end of 2002 of demands and flying hours, are input into Equation 8 to calculate the mean demand for flying hour, X.

$$X = \frac{\sum_{n=1}^{N} x(n)}{\sum_{n=1}^{N} f(n)} \qquad (8)$$

where

X is the *mean demand per flying hour*

N is the *number of periods*

x(n) is the *demand during period n*

f(n) is the *flying hours*

Next, the dependent variable of Equation 8, X, becomes one of the independent variables in Equation 9.

$$V/M = \frac{1}{X(N-1)} \sum_{n=1}^{N} f(n) \left[\frac{x(n)]}{f(n)-X} \right]^2 \qquad (9)$$

where

X is the *mean demand per flying hour*

V/M is the *variance-to-mean*

N is the *number of periods*

x(n) is the *demand during period n*

f(n) is the *flying hours*

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See Appendix D for the Excel spreadsheet that facilitated the necessary calculations. In

short, Equations 8 and 9 provide the VTMRs for the Sherbrooke method.

The sixth method is the variation of Sherbrooke (10 1s). For this method the 10

LRUs that were assigned a VTMR value of 1.00 under the variation of Hill-Stevens

method (10 1s) are changed to a VTMR = 1.00. The other 220 LRUs retained the VTMR

calculated under the Sherbrooke method.

The seventh method is historical data. For the historical data and new regression

function methods, the 230 LRUs are run through an airframe-specific Excel simulation

spreadsheet to randomly distribute their quarterly demands for 2001 and 2002 over the

days of the respective quarter and convert the worldwide to base-level demands. The

simulation spreadsheet calculates the mean, variance and variance-to-mean ratio for each

item. See Appendix E for the layout of the spreadsheet and the visual basic application

behind the simulation's operation for the A-10A. The simulation is applied to the same

LRUs five times. The average VTMR for each of the 230 LRUs from the five

applications is increased to one if less than one and becomes the VTMRs for the

historical data method.

The eighth method is new regression function. For the new regression function

method, the average mean and average variance (again was increased to one if less than

one) for each of the 230 LRUs were input into column 1 and column 2, respectively, of a

JMP data table. Next, the formula VTMR = $a*mean^b$ is entered into the third column.

JMP fits these means and variances to the power function and generated the Fitted

Formula in the fourth column. For this method all 230 LRUs are assigned a VTMR

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calculated from the JMP values for the *a* and *b* parameters in the fitted formula VTMR =

*a*mean^b*. JMP determined *a* = *.005916* and *b* = *.280029*. See Appendix F for the

screen shots of the JMP data table, fitted formula and parameters. Thus, the data in the

fourth column is the VTMRs for the new regression function method.

The ninth method is VTMR = 1 and the tenth method is VTMR = 1.01. Simply

all 230 LRUs were assigned a VTMR of 1.00 and 1.01, respectively.

A scatter plot is shown in Figure 3 of the VTMR verses the mean for the historical

data method, including comments on any observed relationships found is the second and

final step of this first stage. Figure 3 shows most of the 230 data points are in a cluster.

If the mean is less than 50, the majority of the VTMR are less than 1.05. Thus, small

means tend to have low VTMRs. Only about 15 outliers do not fit this relationship.
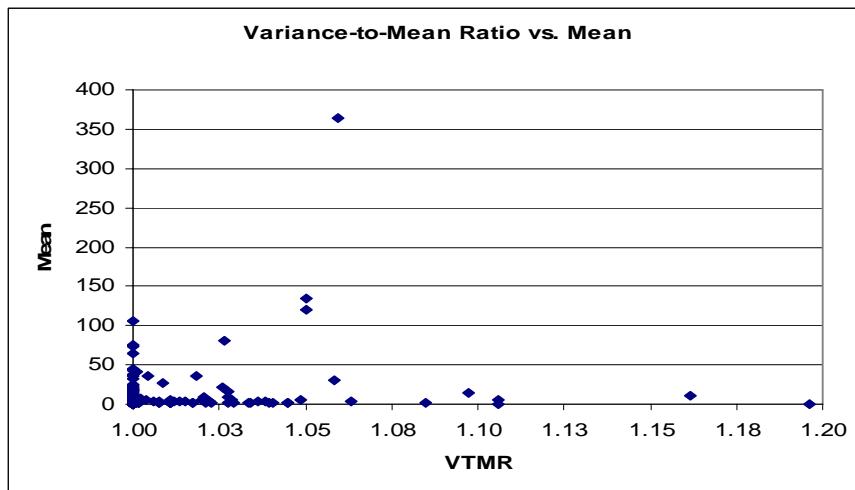
Figure 3. VTMR Verses Mean for Historical Data

The second stage's first step is to set an airframe-specific budget. Since the actual

VTMRs for each LRU could not be extracted from the D200A, baseline VTMRs were

calculated for the target budgets from measurable pipeline quantities. Three equations

are necessary to arrive at these baseline VTMRs. First, the daily demand rate must be calculated from quarterly demands.

$$DDR = \frac{demands}{flying\ hour} \times \frac{flying\ hours}{day} \qquad (10)$$

where *DDR* is *Daily Demand Rate*.

Equation 10 provides the expected number of demands for a reparable per day at a base (Waters and Niklas, 2005). Next, use the DDR to calculate the base pipeline quantity.

$$P_B = DDR \times (1 - NRTS) \times BRC + (NRTS \times OST) \qquad (11)$$

where

P_B is base pipeline quantity

DDR is Daily Demand Rate

NRTS is percentage Not Repairable This Station

BRC is days in Base Repair Cycle, OST is days of Order and Ship Time.

Equation 11 is the base pipeline equation for the calculation of VTMRs (Waters and Niklas, 2005). Now, the pipeline quantity is used to determine the VTMR.

VTMR = 1.132477 * PipelineQuantity ^ .3407513 (12)

where *VTMR* is *variance-to-mean ratio* and *PipelineQuantity* is *mean pipeline quantity*.

Equation 12 is the modified Hill-Stevens equation and was used to calculate a set of baseline VTMRs for the 230 LRUs. Abiding by another modification to the Hill-Stevens equation, the VTMR values were limited to greater than or equal to 1.01 and less than or equal to 5, *1.01 ≤ VTMR ≤ 5*. See Appendix G for the Excel spreadsheet that facilitated the necessary calculations for the baseline VTMRs. At this point, the set of 230 VTMRs was used to determine the airframe-specific budgets. The baseline VTMRs are entered in

to an Aircraft Sustainability Model (ASM) template. Appendix H shows the mandatory

format of this ASM import file named "a10a_k.xls". The first part of the file name is left

to the discretion of the ASM operator, but the file must end with "_k.xls". This is one of

five mandatory files to run ASM. The four other files are "a10a_d.xls",

"A10A_M.DBF", "A10A_P.DBF" and "A10A_P.FPT". The format for "a10a_d.xls"

and "A10A_M.DBF" are in Appendix I. As with the "A10A_M.DBF" file, the

"A10A_P.DBF" and "A10A_P.FPT" files open with a WordPad application. This

application takes up a lot of space in printed works, so the contents of these files will not

be included in this research document. Again naming of the first part of these four

additional files is at the discretion of the ASM operator, but the files must end with

"_d.xls", "_M.DBF", "_P.DBF" and "_P.FPT", respectively. These last four files set

ASM parameters and do not contain VTMRs. To add parameter realism and credibility

to the ASM scenarios, fleet size and average daily flying hours for steady state operations

were obtained from actual bases. Table 3 lists these bases along with the parameters

used.

Table 3. ASM Parameter Values

Airframe	Fleet Size	Average Daily Flying Hours
A-10A	27	30.00
B-2A	20	19.04
F-15E	47	30.89

Next, the five files were imported into ASM for each airframe, aircraft availability was

set to 95%, and A-10A, B-2A, or F-15E ASM scenarios were run to produce airframe-

specific budgets. As a representative sample, Appendix J shows an ASM screen shot

illustrating the resulting budget target for A-10As. In the middle of the screen shot, the

white box beside "Total Buy Cost" reads 199,242. This is the budget target for the

A-10A. The airframe-specific budget targets are summarized in Table 4. Finally, the

second stage's first step is complete.

Table 4. Airframe-Specific Budgets from Baseline VTMRs

Airframe	Budget Target
A-10A	$199,242
B-2A	$68,779,112
F-15E	$7,182,280

The second step of the second stage is to import the variance-to-mean ratios

obtained under each of the ten methods into ASM with the proper budget target. In

preparation for this step, the VTMRs are segregated by airframe type and method. Then

a unique "*_k.xls" file was created for each. That means there are now 30 "*_k.xls" files

and four ASM parameters files, "_d.xls", "_M.DBF", "_P.DBF" and "_P.FPT",

associated with each unique "*_k.xls" file ready for import.   This time the aircraft

availability in ASM was set to 99% in an attempt to maximize the budget before the

aircraft availability. Appendix K is an ASM screen shot for the A-10A using the Hill-

Stevens (H-S) method after the appropriate five files were correctly imported. One at a

time, the 30 sets of five files were imported into ASM in the same manner. After a check

of the screens to ensure the airframe-specific budget target is the correct amount, the

aircraft availability is set to 99% and the other parameters are correct the ASM run is

initiated. Clicking on the Run Requirements bar accomplishes this initiation. The result

of the ASM run is an export file.

The last step of the second stage is to modify the export file. First, Column H, Resupply Days, is added to this Excel spreadsheet. Resupply Days is calculated by dividing total pipeline quantity by total organizational intermediate maintenance demand rate (TOIMDR). In order to calculate Resupply Days on the Excel spreadsheet, divide Tot Pipe 1, column E by Demand 1, column G. Reference Appendix L for a modified F-15E VTMR = 1.01 export file. Resupply Days data is used in the third stage of research design implementation. Continuing with the modification of the export file, column B, (Buy Total) and column C, (Buy Cost) are totaled. In ASM jargon, Buy Total is the number of parts bought and Buy Cost is the total cost of those parts. These two pieces of information for all 30 ASM runs are summarized in a table and presented in Chapter 4. They will be used for comparison purposes between the ten variance-to-mean ratio methods. The second stage is complete.

The third stage in the research design implementation employs an Excel simulation. After loaded with information from the modified ASM export file, the simulation randomly allocates the demands for fiscal year 2003 and then determines the expected backorders and aircraft availability under each of the methods. Refer to Appendix M to see an example layout of the simulation and the visual basic application (VBA) behind the simulation's operation for the B-2A under the Sherbrooke method.

The first step in this third stage is to load the appropriate data from the modified ASM export file into the Excel simulation. First, Copy, Paste Special, Transpose, column B, Buy Total from the modified ASM export file into the Data Worksheet, row 2, Spares in the Excel simulation. This step provides the stock level of each LRU bought under

each method. Second, <u>C</u>opy, Paste <u>S</u>pecial, Transpos<u>e</u>, column H, Resupply Days from the modified ASM export file into the Data Worksheet, row 3, Resupply Days in the simulation. This step provides the number of days required to receive the LRU when the stock level is zero and a demand exists. Resupply Days only has to be loaded in the three airframe-specific simulations because they do not change from method to method. Similar to the ASM runs, it takes 30 simulation spreadsheets to accomplish this stage. Each of the ten methods has a set of three airframe-specific simulations for a total of 30. The Excel simulations are now loaded with the appropriate data from the modified ASM export file and first step in the third stage is complete.

The third stage's final step is to obtain the results from the simulations in order to answer the research question. To activate each simulation, click on the Populate Demands command button in the Demands Workbook. The quantitative expected backorder and aircraft availability percentage result. Each of the 30 simulations is run five times to compensate for the randomized FY2003 quarterly demands distribution. The average aircraft availability percentage combined with the total cost of the parts theoretically purchased determines which method provided the biggest bang for the buck. Thus, this final progressive stage of the research design implementation provided the information necessary to answer the research question.

Significance of the Research

The significance of this study is aircraft availability and cost savings. This research attempts to answer a simple question. Is Hill-Stevens still the best method for achieving the highest aircraft availability rates in today's environment of constrained

budgets? Speculation within the HQ AFMC/A8S suggests other options may exist for calculating variance-to-mean ratios to more effectively predict future-quarter stockage levels. Conceptually, testing alternative methods to calculate VTMRs using identical ASM scenarios and FY 03 LRU demand data represent a strong methodology for comparison. The results of this research may offer the USAF a better business practice for achieving higher aircraft availability rates at lower cost.

Expected Results

Expected results are open for debate and can be convincingly argued for any method. For example, it might be argued raw historical data based on actual events is more significant than methods using seemingly arbitrary equations. Conversely, it might be argued variance-to-mean ratios based on program element information such as flying hours may produce more accurate results. Also, method and/or ASM software caps on VTMRs for the Sherbrooke method and elimination and unweighted grouping of LRUs in the Hill-Stevens method skew results because not all data are equally considered. Methods with higher cost of inventory will probably yield higher availability rates. Regardless of method limitations and rationale, definitive linear differences between methods are expected.

Summary

The variance-to-mean ratio methods of Hill-Stevens and Sherbrooke prompted this research. However, eight other alternatives for determining stockage

levels of reparable using variance-to-mean ratios were also studied: base pipeline

quantity, Hill-Stevens (10 1s) - supplemented with VTMR=1 for eliminated items, Hill-

Stevens (230 LRUs), a variation of Sherbrooke (10 1s), historical data, a new regression

function, variance-to-mean ratio equals 1.00 or variance-to-mean ratio equals 1.01.

     The purpose of this chapter was to detail the research steps used to achieve a

systemic framework for obtaining unbiased results when comparing the ten above-

mentioned alternatives for calculating VTMRs.

     This chapter described the methodology used for the research, including the

research objectives, data selection, research design, research questions, research design

implementation, significant of the research, and expected results.

IV. Analysis and Results

Chapter Overview

This chapter analyzes the ten methods in this study based on identical raw worldwide quarterly organizational intermediate maintenance (OIM) demands for LRUs. The procedure begins with collecting raw demands from the Ddb04 table of the D200A Secondary Item Requirement System (SIRS) and preparing these demands to calculate VTMRs for use in an Aircraft Sustainability Model (ASM) scenario. The ASM scenario application produced the inventory of spare parts required under each method and enabled calculation of the inventory's total cost. Additionally, the ASM scenario application calculated the number of resupply days for each LRU. An Excel simulation used the inventory of spare parts and the number of resupply days for each LRU to calculate expected backorders and aircraft availability. Once the percentage of aircraft available was identified, it was matched with the inventory's total cost and a comparison was made to determine which of the ten methods studied produced the biggest bang for the buck.

Data Collection and Preparation

The purpose of data collection and preparation was to calculate the variance-to-mean ratios (VTMRs, VMRs, V/Ms) for the ten methods in this study: base pipeline quantity, Hill-Stevens (220 LRUs), a variation of Hill-Stevens (10 1s), Hill-Stevens (230 LRUs), the Sherbrooke, a variation of Sherbrooke (10 1s), historical data, a new

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regression function, variance-to-mean ratio equals 1.00 or variance-to-mean ratio equals 1.01.

Data collection and preparation took thirteen steps. It started with raw data collection from the D200A system and the flying hour programs. Next, spreadsheet calculations were used to derive VTMRs for inclusion in the ASM import template.

In the first step, worldwide quarterly OIM demands and flying hour raw data supplied by HQ AFMC/A8S was drawn for unique line-replaceable units (LRUs) on A-10A, B-2A, C-17A and F-15E aircraft. The data was selected from D200A's Ddb04 tables and flying hour programs respectively. The two workbook (OIM Demands and Program Data) spreadsheet provided by HQ AFMC/A8S contained 815 records (one for each 815 airframe unique LRU) with fields of sub group master (SGM)/part number, next higher assembly (NHA)/airframe type, actual quarterly demands and actual quarterly flying hours from the first quarter of fiscal year (FY) 1987 through the fourth quarter of FY2003 (SumOf3FY87 through SumOf4FY03). Table 5 shows the original raw data spreadsheet with hidden columns and rows.

Table 5. Raw Data Spreadsheet

	A	B	C	D	E	BP	BQ	BR
1	OIM							
2		SGM	NHA	SumOf3FY87	SumOf4FY87	SumOf3FY03	SumOf4FY03	
4		005679423	A010A	19	16	2	3	
5		005764880	A010A					
6		005836015	A010A	1	0	0	2	
7		005956890	A010A	22	10	11	13	
8		006070306	A010A	1	0			
513		014499903	B002A			0	1	
514		014502338	B002A			0		
515		014518801	B002A			0	0	
516		014525932	B002A			0	0	
517		014527228	B002A					
555		013399252	C017A			1	4	
556		013506412	C017A					
574		014830891	C017A				2	
582		011448068	F015E	1	0	2	1	
583		011773499	F015E			0	1	
584		011945671	F015E					
585		012257451	F015E	0	0	158	125	
810		015097159	F015E					
811								

|◄ ◄ ► ►|\ **OIM Demands** / Program Data /

During the second step, the data was examined to find at least sixteen quarters of reliable data. In other words, quarters with blank data were eliminated as unreliable

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where quarters with "0" demands were kept. This assessment eliminated the third quarter of FY 1987 through the fourth quarter of FY 1999 and 430 LRUs because of unreliable data. Although the Central Limits Theorem (CLT) requires at least 30 observations to qualify a sample as significantly large, more than three years (twelve quarters) of demands would be detrimental in this case because as Sherbrooke proved in his 2004 study, "the variance-to-mean ratio increases with the length of the time period over which it is measured". For this reason, it is assumed three years of demand data to calculate the VTMRs and one year of holdout demand data to evaluate the methods are optimal. Of the remaining 385 LRUs only 11 were from the C-17A. These 11 were also eliminated because they did not meet the Central Limits Theorem (CLT) qualification of a significantly large sample. Additionally, 11 LRUs would not generate a satisfactory budget target, inventory or aircraft availability for comparison purposes. Another 144 LRUs were removed for this study because they lacked a positive-demand value for the holdout year of 2003 and/or their quarterly flying hour data was not complete for the entire four-year period.

Identifying the remaining 230 LRUs and their associated data was the third step. In order to begin the procedures used to develop variance-to-mean ratios under each method in an organized matter, a new/smaller spreadsheet was created.

The fourth step is calculating the VTMRs for the base pipeline quantity method. The spreadsheet in Appendix G along with Equation 12 were used to calculate the VTMRS for this method. This method represents the VTMRs currently used in USAF supply system

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Calculating the VTMRs for the Hill-Stevens method is the fifth step. With the assistance of an Excel spreadsheet, the detailed methodology previously described in the Research Design Implementation section in Chapter III was followed. The Hill-Stevens method starts with the same 230 LRUs but ends up with VTMRs for only 220 LRUs because their method eliminated items with over 70 % of their total demands in the first or second year.

For the sixth step, the 220 LRUs assigned a VTMR under the Hill-Stevens method were assigned the same VTMR, but the 10 LRU not assigned a VTMR under the Hill-Stevens method were assigned a VTMR of one. VTMR of one was selected because it is the standard assumption in inventory theory. This supplements the Hill-Stevens method and creates a variation of the Hill-Stevens method.

The seventh step calculated VTMRs for Hill-Stevens (230). For this method all 230 LRUs are assigned a VTMR calculated from the JMP values for the *a* and *b* parameters in the fitted formula $Y=a*m^b$. JMP determined *a = .287695* and *b = .775911*. Reference Appendix C.

Aided by the spreadsheet in Appendix D, calculating the VTMRs for the Sherbrooke method is the eighth step. This spreadsheet breaks the long and difficult looking Equations of 8 and 9 down into smaller, more manageable pieces.

The ninth step is the variation of Sherbrooke (10 1s). For this method the 10 LRUs that were assigned a VTMR value of 1.00 under the variation of Hill-Stevens method (10 1s) are changed to a VTMR = 1.00. The other 220 LRUs retained the VTMR calculated under the Sherbrooke method.

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For the historical data method and the tenth step, the 230 LRUs and their demands for FY 2001 and FY 2002 were formatted in an airframe-specific Excel simulation and readied for calculating variance-to-mean ratios (VTMRs, VMRs, V/Ms). The demands are based on worldwide demand rates and had to be converted to a single base demand rate. This calculation was accomplished in the simulation by dividing the worldwide quarterly demand by the number of bases for the appropriate airframe and then rounding up to the next whole number. Table 6 lists the number of bases used for the simulation. With the exception of the B-2A, these are not the actual number of bases that have the airframe. Instead, the number of bases is a proportion of the total USAF fleet divided by the fleet size of the base model for the research.

Table 6. Number of Bases for VTMR Calculation Simulation

Airframe	Number of Bases
A-10A	13
B-2A	1
F-15E	8

Reference Appendix E for the layout of the simulation used in this seventh step to calculate the VTMRs for the historical data method.

The eleventh step used the variance-to-mean ratios calculated in step 8 and processed them through the statistical JMP software to calculate the VTMRs for the new regression function method. Refer to the Research Design Implementation section in Chapter III and Appendix F for a comprehensive explanation of the procedure undertaken to arrive at the VTMRs for the new regression function method.

The twelfth step combines the two methods of VTMR = 1.00 and VTMR = 1.01. All 230 LRUs were assigned a VTMR of 1.00 and 1.01, respectively. Without a doubt,

these last two methods are the easiest VTMRs to calculate because they require no spreadsheets, equations, simulations or statistical software.

The thirteenth and final preparatory step populated the ASM import template with the variance-to-mean ratios calculated in the previous steps. An example of the data intensive ASM import template is in Appendix H. This final step produces 30 ASM import templates, one for each of the ten methods times the three airframes in this study.

Aircraft Sustainability Model Input

Driven by several factors including variance-to-mean ratios, the Aircraft Sustainability Model (ASM) optimizes the set of spare parts required to maintain a specified flying scenario. In the case of this research, the set of spare parts is an inventory of reparables. Before running an ASM scenario, parameters must be set. ASM parameters include VTMRs, aircraft fleet size, average daily flying hours and targeted budgets for each airframe. The VTMR parameter was used to adjust the item's demand uncertainty. ASM only accepted VTMRs from 1.00 to 7.00. All other parameters being the same, increasing levels of uncertainty drive higher VTMR values and greater spares requirements to meet the budget targets (ASM User's Manual, Version 7.46, September 2004). Parameters were provided through the import routine described in the Research Design Implementation section of Chapter III. The routine started with the ASM import template and four other import files. With parameters set, scenarios for each of the ten methods were run for each of the three airframes in this study. The 30 runs created 30 export files. ASM identified an inventory of reparables in each export

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file. Data embedded in the export file was used to calculate the number of resupply days

necessary for a backordered LRU and the total cost of the inventory. Reference

Appendix L for a modified F-15E VTMR = 1.01 export file. The set of spare parts and

resupply days data were required to continue the procedure in the Excel simulation.

Excel Simulation

        The purpose of the Excel simulation was to calculate the percentage of aircraft

availability based on the set of spare parts, resupply days of each LRU and random FY

2003 demands dispersed throughout the respective quarters.

        First, the inventory of reparables and resupply days were entered into the

spreadsheet. Next, a visual basic application (VBA) code was run to randomly position

the demands in the appropriate quarter. Once the demand data was randomly placed,

another sheet in the simulation checked to see if a spare was available to fill the demand.

If the spare could be pulled from inventory, it was. If the inventory had a zero balance

for that LRU, a backorder was created based on the number of resupply days calculated

from the ASM export file. Once the code was complete, a final Excel cell calculated

aircraft availability percentage with Equation 13.

$$AA = e^{-\left(\frac{\sum Backorders}{\#Aircraft} \right)} \quad (13)$$

where

AA is *aircraft availability percentage*

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Backorders is *average daily backorders*

$\#\,Aircraft$ is *fleet size*

Reference Table 3 for airframe-specific fleet size and Appendix M for the layout of the

Excel simulation and the visual basic application (VBA) code behind the simulation.

Each of the 30 simulations was run five times to compensate for the randomized FY 2003

quarterly demands placement. See Appendix N for the aircraft availability percentage

results of the five runs for each of the three airframes and the average aircraft availability

percentage. The average aircraft availability percentage for the system (all three

airframes) compiled with the total cost of the parts theoretically purchased under each

method determines which method provided the biggest bang for the buck. Table 7 shows

these results for the ten methods.

Table 7. AA and Cost of Inventory for the Ten Methods

Method	System Average AA	Total Cost
1. Base Pipeline Quantity	89.7%	$76,148,482
2. Hill-Stevens (220)	89.1%	$76,039,300
3. Hill-Stevens (10 1s)	91.1%	$75,024,262
4. Hill-Stevens (230)	91.0%	$76,039,300
5. Sherbrooke	90.8%	$75,780,468
6. Sherbrooke (10 1s)	90.9%	$75,968,807
7. Historical Data	85.6%	$76,013,071
8. New Regression	85.9%	$76,019,505
9. VTMR=1.00	85.7%	$76,008,127
10. VTMR=1.01	85.8%	$76,124,852

A comparison of the results determined Method 3, a variation of the Hill-Stevens method (the 10 LRUs not assigned a VTMR under the Hill-Stevens method was assigned a VTMR of 1.00), produced the highest aircraft availability of 91.1% and lowest total cost of $75,024,262 for the best bang for the buck.

Investigative Questions Answered

The following specific investigative questions were answered to support the comparisons of the variance-to-mean ratios for the ten methods:

1. Are the calculated VTMRs from the ten methods comparable?

Since the VTMRs were calculated from an identical set of actual raw demands for each of the ten methods, this makes them comparable.

2. Is there a relationship between the means and VTMRs?
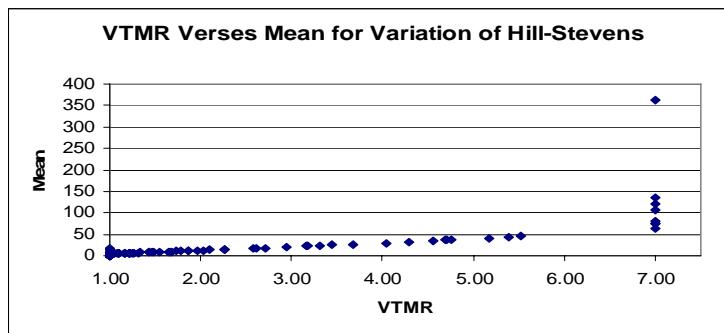
Figure 4. VTMR Verses Mean for Variation of Hill-Stevens

The scatter plot in Figure 4 of the VTMR verses the mean for the variation of the Hill-Stevens method shows a linear relationship. As the mean increases, so does the VTMR. The VTMRs in Figure 4 are capped at 7.00 because this is the highest VTMR value allowed by the Aircraft Sustainability Model (ASM).

3. Do the results provided by the Aircraft Sustainment Model (ASM) permit an adequate comparison of the methods?

The results provided by the Aircraft Sustainment Model (ASM) provide an adequate comparison of the methods because the same scenario is used every time a set of VTMRs are input into ASM. Furthermore, in an effort to avoid human error when setting the scenario parameters, only the VTMRs are changed in the ASM import files.

4. Will an Excel simulation spreadsheet using demands for fiscal year (FY) 2003 to calculate aircraft availability add more value than if FY 2003 demands were not used for the evaluation?

Since the VTMRs were calculated from FY 2000 through FY 2002 demands, the simulation spreadsheet adds realism by using demands for fiscal year FY 2003. Artificial demands would not provide as compelling of a test. Additionally, the simulation spreadsheet visual basic application (VBA) code adds value by randomizing the demands across their respective quarter. The final aircraft availability obtained from the use of the simulation is an average of five runs. An average instead of a single result is often more representative and adds value.

5. Which method of estimating VTMR yields the lowest total cost and the highest aircraft availability, the biggest bang for the buck?
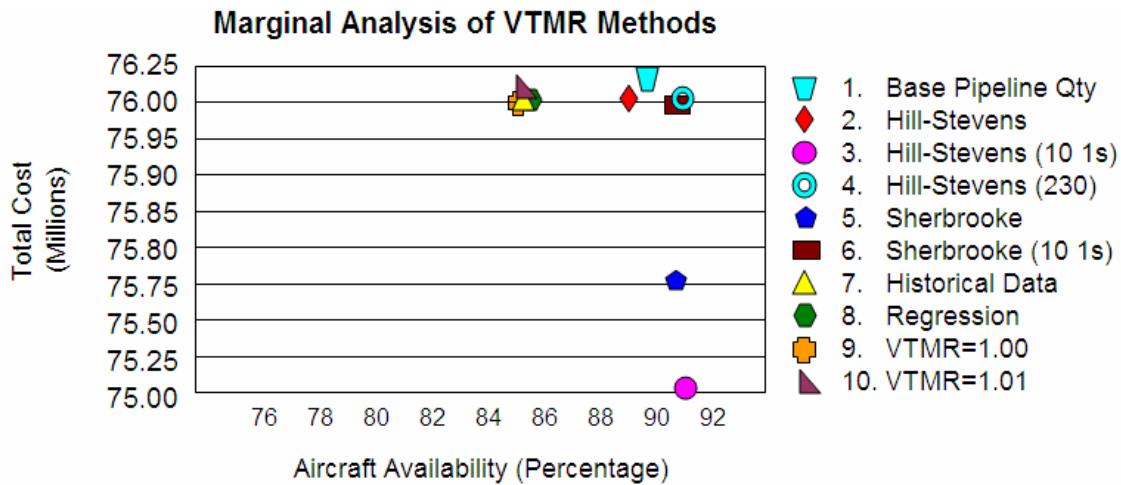
Figure 5. Graph of Results from Ten VTMR Methods

As depicted in Figure 5, the variation of Hill-Stevens method (the 10 LRUs not assigned a VTMR under the Hill-Stevens method was assigned a VTMR of 1.00) of estimating VTMR yields the biggest bang for the buck.

Summary

The process described here seemingly difficult in execution is rather straightforward in concept. The process simply applied an identical set of actual raw demand data to determine variance-to-mean ratios (VTMRs, VMRs, V/Ms) for each the ten methods in this study. Once those VTMRs were identified, they were processed through a standard set of ASM scenarios and Excel simulations for each of three airframes (A-10A, B-2A, and F-15E) to determine aircraft availability. An analysis of those results were used to answer the research question: Will the base pipeline quantity, Hill-Stevens (220 LRUs), a variation of Hill-Stevens (10 1s), Hill-Stevens (230 LRUs), the Sherbrooke, a variation of Sherbrooke (10 1s), historical data, a new regression

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function, variance-to-mean ratio equals 1.00 or variance-to-mean ratio equals 1.01, yield

the highest aircraft availability given the same reparables budget?

V. Conclusions and Recommendations

Chapter Overview

Chapter IV provided results from which conclusion can be drawn and recommendation can be made. This chapter will present the conclusions of the research, discuss the significance of the research and recommend topics for future research.

Conclusions of Research

In short, the variation of the Hill-Stevens method provided the highest aircraft availability percentage with the lowest budget. To review, those LRUs not assigned a VTMR under the Hill-Stevens method was assigned a VTMR of one to supplement the Hill-Stevens method and created the second alternative, a variation of Hill-Stevens method. The variance-to-mean ratio (VTMR, VMR, V/M) does have an effect on aircraft availability (AA) and budget and not surprisingly, there was a notable difference in the number of parts bought. The variation of the Hill-Stevens method did not buy the least number of line-replaceable units (LRUs). Matter of fact, it bought the next to highest number of LRUs. In reparables inventory management the amount of space required to store the parts must often be taken into consideration when choosing a stockage method. Table 8 illustrates the difference in number of LRUs theoretically purchased under each of the ten methods.

Table 8. Number of LRUs Theoretically Purchased Under Each Method

Method	Number of LRUs Theoretically Purchased
Base Pipeline Quantity	662
Hill-Stevens (220 LRUs)	498
Variation of Hill-Stevens (10 1s)	500
Hill-Stevens (230 LRUs)	496
Sherbrooke	803
Variation of Sherbrooke (10 1s)	824
Historical Data	419
New Regression Function	423
VTMR=1.00	422
VTMR=1.01	426

Although the variation of the Hill-Stevens method (the 10 LRUs not assigned a VTMR under the Hill-Stevens method was assigned a VTMR of 1.00) performed best in the criterion established for this research, it may not be the best VTMR method for every situation.

Significance of Research

In the world of logistics, inventory management and supply chain management, all participants are concerned with effective inventory stock levels at low cost. The results of this research indicated a significant cost savings of $1,124,219.58 can be realized along with an aircraft availability improvement of 1.4 percent over the baseline 89.7 percent.

Recommendations for Future Research

Anywhere an agency relies on available supplies to keep the mission moving can benefit from a VTMR method promising high availability at low cost. For example, Boeing, Lockheed-Martin, NASA, USAF, and the United States Navy all use the Aircraft Sustainment Model (ASM) (Niklas, 23 March 2005) and some sort of a VTMR method to determine availability. In other words, many agencies could benefit from a more comprehensive study than offered by this limited research. The apparent significance of the VTMR on aircraft availability warrants further research.

This research indicates opportunity exists for improving the cost effectiveness and aircraft availability percentage with application of a variance-to-mean ratio decision point. Future research could take an in-depth look at these ten methods with expanded data ranges, higher number of LRUs and a limited number assumptions. This research used too many assumptions to satisfy a decision-making threshold. For example, the ASM limits the VTMR value to 7.00, the raw data could have been more recent, only three airframes were used, and worldwide demands had to be converted to a single base. All exercises are artificial. Anther suggestion is to modify reports from the supply system to allow/produce data for base-level demands.

Though ASM is the accepted HQ AFMC/A8S software of choice, it is still a model and only as good as the programming. The assumptions in the ASM code are unknown. Future research should include a study done base by base for different LRUs, fleet sizes, flying hours and transportation/distribution factors.

Summary

This thesis had a two-fold focus. The first was to provide insight into the sensitivity of the variance-to-mean ratio (VTMR, VMR, V/M). Table 9 reveals the VTMRs' mean, the range of the VTMRs, and whether daily or quarterly demands were used to calculate the VTMRs for each of the ten methods evaluated by ASM and the Excel simulation.

Table 9. **Variance-to-Mean Ratio Differences Under Ten Methods**

Method	VTMR Mean	VTMR Range	Quarterly or Daily Demands
1. Base Pipeline Quantity	2.41	1.01-5.00	Daily
2. Hill-Stevens	1.53	1.00-7.00	Quarterly
3. Hill-Stevens (10 1s)	1.51	1.00-7.00	Quarterly
4. Hill-Stevens (230)	1.53	1.00-7.00	Quarterly
5. Sherbrooke	1.53	1.00-7.00	Quarterly
6. Sherbrooke (10 1s)	1.53	1.00-7.00	Quarterly
7. Historical Data	1.01	1.00-1.20	Daily
8. New Regression	1.01	1.00-1.03	Daily
9. VTMR=1.00	1.00	1.00-1.00	Not Applicable
10. VTMR=1.01	1.01	1.01-1.01	Not Applicable

This research is limited to ten methods of determining variance-to-mean ratio (VMTR) and four years of demand data. These limitations are necessary to keep the scope of the research manageable. Three years of quarterly demands were available to calculate the VTMRs under each method and the forth year was used in the simulation spreadsheet for the evaluation of the VTMRs. Given these limitations, this thesis still provided the information necessary for the second half of its two-fold focus. It determined a variation of the Hill-Stevens method (the 10 LRUs not assigned a VTMR under the Hill-Stevens method was assigned a VTMR of 1.00) produced the lowest total cost and the highest aircraft availability, thus, the biggest bang for the USAF buck.

Appendix A. Acronyms

AA   Aircraft Availability

AAM   Aircraft Availability Model

AF   Air Force, referring to the United States Air Force

AFB   Air Force Base

AFLC   Air Force Logistics Command

AFLMA   Air Force Logistics Management Agency

AFM   Air Force Manual

AFMC   Air Force Materiel Command

ALS   Advanced Logistics System

ANGB   Air National Guard Base

ASM   Aircraft Sustainability Model

BAI   Backup Aircraft Inventory

BRC   Base Repair Cycle

DAU   Defense Acquisition University

DDR   Daily Demand Rate

DLM   Depot Level Maintenance

DoD   Department of Defense

EOQ   Economic Order Quantity

ERRC   Expendability, Recoverability, Repair Code

EXPRESS   Execution and Prioritization of Repair Support System

FSC   Federal Stock Class

H-S   Hill-Stevens Method

HQ	Headquarters
LMI	Logistics Management Institute Government Consulting Company
LRU	Line-Replaceable Unit
METRIC	Multi-Echelon Technique for Recoverable Inventory Control
MMAC	Materiel Management Aggregation Code
NIIN	National Item Identification Number
NRTS	Not Repairable This Station
NSN	National Stock Number
O&ST	Order and Ship Time
OIM	Organizational Intermediate Maintenance
OST	Order and Ship Time
PAA	Primary Aircraft Assigned/Authorized
QPA	Quantity Per Application
RBL	Readiness-Based Leveling
RCDL	Repair Cycle Demand Level
SAC	Strategic Air Command
SGM	Sub Group Master
SRU	Shop-Replaceable Unit
TOIMDR	Total Organizational Intermediate Maintenance Demand Rate
USAAF	United States Army Air Forces
USAF	United States Air Force
V/M	Variance-To-Mean Ratio
VBA	Visual Basic for Applications)

VMR	Variance-To-Mean Ratio
VSL	Variable Safety Level
VTMR	Variance-To-Mean Ratio
XD	Expendability, Recoverability, Repair Code (ERRC) / Depot Level
XF	Expendability, Recoverability, Repair Code (ERRC) / Field Level

Appendix B. Glossary

Advanced Logistics System   Predecessor of D200A, never fully developed due to
technological limitations

Aircraft Sustainability Model   Computes mission-ready spares packages that provide
the best mission readiness at the lowest cost.

Backup Aircraft Inventory   Number of aircraft at a base above the primary aircraft
assigned/authorized

D200   System that determines the spare parts requirements for the Air Force,
composed of many subsystems that perform many different functions

D200A   Secondary Item Requirement System (SIRS), subsystems of D200,
computes the buy, repair, excess, and termination requirements for Air
Force managed recoverable and consumable items each quarter

Depot Level Maintenance   A demand that occurs at a depot is considered a DLM
demand. Examples of DLM demand: programmed depot maintenance, an
engine overhaul.

Economic Order Quantity   A model that defines the optimal quantity to order that
minimizes total variable costs required to order and hold inventory.

Federal Stock Class   First 4 digits of the national stock number (NSN)

Line-Replaceable Unit   A part typically removed from an aircraft when undergoing
maintenance other than adjustment, calibration, or servicing. Repair for the
majority of these occur at the depot level.

Multi-Echelon Technique for Recoverable Inventory Control   Finds the best balance
of spares at the depot and bases to minimize the base-level backorders.

Materiel Management Aggregation Code   The last two digits of the National Stock
Number (NSN)

National Item Identification Number   The 9 digits after the Federal Stock Class (FSC)
in the National Stock Number (NSN), each Air Force item has a unique one,
simply an abbreviated part number

Not Repairable This Station   Designation given to a repairable part whose repair is
beyond the capacity of maintenance at a particular location

National Stock Number   Each Air Force item has a unique one.

Order and Ship Time   Number of days it takes the depot to send a serviceable replacement part to the base.

Organizational Intermediate   Maintenance (base-level maintenance)   Any maintenance not considered Depot Level Maintenance (DLM), a demand that occurs at a base is considered an OIM demand.

Quantity Per Application   The number of parts of a particular type installed on the part's next higher assembly

Readiness-Based Leveling   This system (D035E) at HQ AFMC computes base and depot levels for selected (XDx) items. It is designed to allocate the D200 worldwide peacetime requirements among Air Force bases and   depots to minimize base expected backorders.

Repair Cycle Demand Level   Predecessor of Readiness-Based Leveling

Strategic Air Command   Predecessor of Air Combat Command (ACC)

Shop-Replaceable Unit   A subassembly of a Line-Replaceable Unit (LRU), typically replaced during repair of the LRU

United States Army Air Forces   Direct precursor to the United States Air Force, formally existed between 1941 and 1947

Variance-To-Mean Ratio   The unbiased estimator of the variance of a process divided by its mean

Variable Safety Level   A spares requirement estimation method, derived directly from the Multi-Echelon Technique for Recoverable Inventory Control (METRIC) by C.C. Sherbrooke

XD Expendability, Recoverability, Repair Code (ERRC)   An item repaired at depot level, a depot reparable

XF Expendability, Recoverability, Repair Code (ERRC)   An item where repaired/disposition decision made at the field (base) level

Appendix C. JMP Screen Shots for the Hill-Stevens Method

	Mean	VTMR Formula	VTMR	Fitted VTMR Formula
1	0.25	0.09812684	1.18367347	0.09812684
2	0.375	0.1344061	1	0.1344061
3	0.5	0.16801976	1	0.16801976
4	0.625	0.19978087	1	0.19978087
5	0.75	0.23013968	1.07692308	0.23013968
6	0.875	0.25937987	1.24803768	0.25937987
7	1	0.28769537	1.5	0.28769537
8	1.125	0.31522647	1.06349206	0.31522647
9	1.25	0.34207901	1.54285714	0.34207901
10	1.375	0.36833541	1.35844156	0.36833541
11	1.5	0.39406152	1.63809524	0.39406152
12	1.625	0.41931108	1.83516484	0.41931108
13	1.75	0.44412865	1.61904762	0.44412865
14	1.875	0.46855178	1.83428571	0.46855178
15	2	0.49261245	1	0.49261245
16	2.125	0.51633826	1.22408964	0.51633826
17	2.25	0.53975317	1.87301587	0.53975317
18	2.375	0.56287822	1.50827068	0.56287822
19	2.5	0.58573199	3.77142857	0.58573199
20	2.625	0.60833101	1	0.60833101
21	2.75	0.63069006	1	0.63069006
22	2.875	0.65282244	1	0.65282244
23	3	0.67474015	2.76190476	0.67474015
24	3.125	0.6964541	1.57904762	0.6964541
25	3.25	0.71797423	1.2967033	0.71797423
26	3.375	0.73930963	1.37742504	0.73930963
27	3.5	0.76046864	1.42857143	0.76046864
28	3.75	0.80228765	1.04761905	0.80228765
29	3.875	0.82296132	1.70353303	0.82296132
30	4	0.84348605	2.21428571	0.84348605
31	4.75	0.96380009	1	0.96380009
32	4.875	0.98342223	1	0.98342223
33	5.125	1.02233265	3.14634146	1.02233265
34	5.25	1.04162759	1.34693878	1.04162759
35	5.5	1.07991235	1	1.07991235
36	5.625	1.09890785	1.82539683	1.09890785
37	6.125	1.17397064	2.10398445	1.17397064
38	6.275	1.21008284	11.3361345	1.21008284
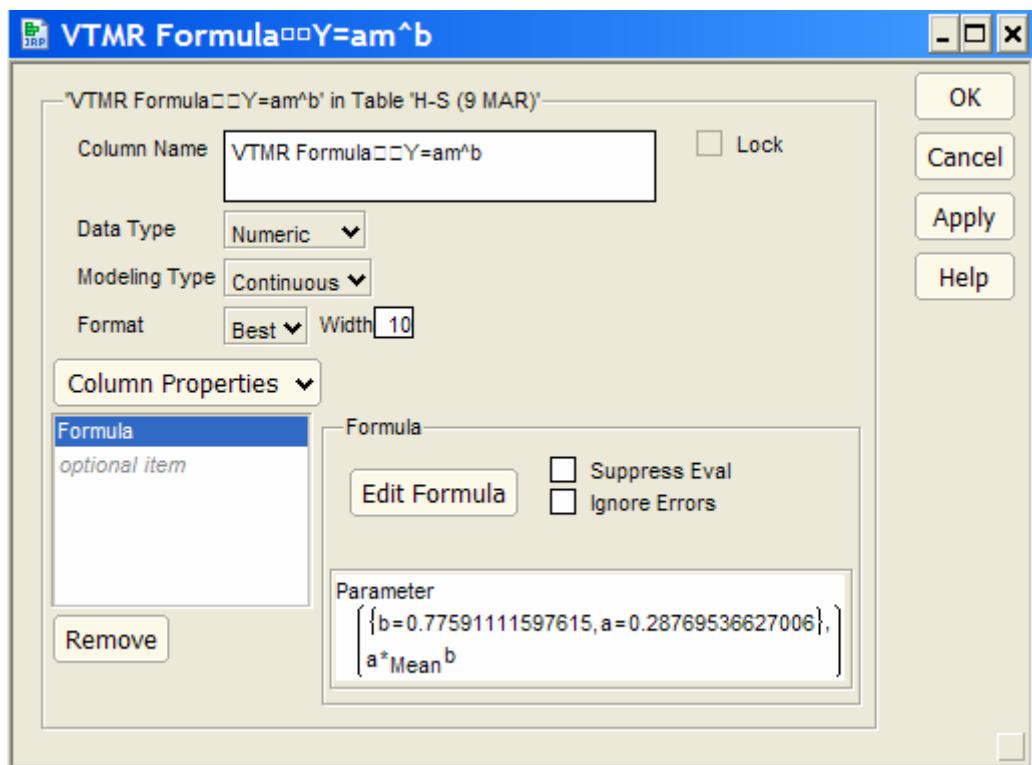
Appendix D. Excel Spreadsheet to Facilitate Sherbrooke Calculations

		Fly Hours			Demands			X	n=1	n=8	n=1 to n=8		
SGM	NHA	1FY01	4FY02	Sum f(n)	1FY01	4FY02	Sum x(n)	Sum x(n)/Sum f(n)	f(n)[x(n)/f(n)-X]^2	f(n)[x(n)/f(n)-X]^2	Sum f(n)[x(n)/f(n)-X]^2	1/X(N-1)	V/M
005836015	A010A	358	360	3011	0	0	5	0.001661	0.000000	0.000000	0.018812	86.02857143	1.618382
005956890	A010A	358	360	3011	6	13	65	0.021588	0.100571	0.469501	1.710913	6.617582418	11.322106
010035568	A010A	179	180	1506	7	6	51	0.033865	0.273847	0.200075	2.013894	4.218487395	8.495588
013977533	A010A	179	180	1506	22	29	187	0.12417	2.707666	4.678675	26.600934	1.150496562	30.604283
014543400	A010A	161	162	1355	7	9	89	0.065683	0.304596	0.500406	6.281308	2.174959872	13.661593
011904934	B002A	389	345	3267	5	2	27	0.008264	0.064270	0.011595	0.299832	17.28571429	5.182812
012013256	B002A	12	14	127	3	1	19	0.149606	0.769056	0.072980	4.071671	0.954887218	3.887986
012572448	B002A	24	28	253	0	1	5	0.019763	0.000000	0.035765	0.209637	7.228571429	1.515373
014674875	B002A	48	56	503	0	0	3	0.005964	0.000000	0.000000	0.041209	23.95238095	0.987048
993960449	B002A	24	28	253	1	0	4	0.01581	0.041722	0.000000	0.144189	9.035714286	1.302851
997714157	B002A	12	14	127	0	0	5	0.03937	0.000000	0.000000	0.429898	3.628571429	1.559915
011448068	F015E	763	853	7032	1	0	2	0.000284	0.001311	0.000000	0.002457	502.2857143	1.234320
012247827	F015E	362	440	3551	83	58	595	0.167558	19.048016	7.651281	106.219860	0.852581032	90.561038
014590687	F015E	121	147	1184	3	43	213	0.179899	0.074602	12.609074	49.075154	0.794097921	38.970478
014632311	F015E	241	294	2368	571	345	2911	1.229307	1366.775117	408.253880	4164.998135	0.116209452	484.012150
014686073	F015E	7	315	1645	0	4	18	0.010942	0.000000	0.050797	0.935234	13.05555556	12.209997
014689407	F015E	4	40	212	0	7	25	0.117925	0.000000	1.232255	3.544634	1.211428571	4.294071

Cell	Formula
K3	=SUM(C3:J3)
T3	=SUM(L3:S3)
U3	=T3/K3
V3	=C3*(L3/(C3-U3))^2
AC3	=J3*(S3/(J3-$U3))^2
AD3	=SUM(V3:AC3)
AE3	=1/(U3*7)
AF3	=AE3*AD3

Appendix E. Layout of Excel Simulation and Visual Basic Code

	A	B	C	J	K	R	S	T	X	Y	Z	AA	AB	AC	AD
1	SGM	NHA	1FY01	4FY02	1FY01	4FY02	Bases	1st run	5th run	Avg VTMR	Total Worldwide Demand	Total Demands Per Bas	Base Demands X # bases	Difference Actual vs. Allocate	Runs Different VTMRs
2	005836015	A010A	0	0	0	0	13	0.995873	0.995873	0.995873	5	4	52	10.40	YES
3	005956890	A010A	6	13	0	1	13	0.994498	0.994498	0.994498	65	5	65	1.00	YES
35	013977533	A010A	22	29	2	2	13	0.982118	0.982118	0.982118	187	14	182	0.97	YES
36	014543400	A010A	7	9	1	1	13	0.990371	0.990371	0.990371	89	8	104	1.17	YES
37														Avg of diff	
38														3.08	

Apply

The simulation was run 5 times to determine the average VTMRs.

	A	B	C	J	K	R	S	T	X	Y	Z	AA	AB	AC	AD
180	variance	0.005472	0.00683	0.005472	0.002743	0.009536	0.033388	0.001374	0.026755	0.009536	0.010883	0.005472	0.001374	0.002743	0.01088
181	mean	0.005495	0.006868	0.005495	0.002747	0.009615	0.031593	0.001374	0.027473	0.009615	0.010989	0.005495	0.001374	0.002747	0.01099
182	VTMR	0.995873	0.994498	0.995873	0.998624	0.991747	1.056815	1	0.973865	0.991747	0.990371	0.995873	1	0.998624	0.99037

183		005836015	005956890	010164850	010222634	010348993	010351386	010352338	010436531	010472304	010533195	010723536	011041626	011685153	012039792
184	Yr-1 Q-1	0	0	0	0	1	3	0	1	1	1	1	0	0	1
185	Yr-1 Q-2	1	1	0	1	1	3	0	2	0	1	0	0	1	1
186	Yr-1 Q-3	0	1	1	1	1	2	1	2	1	1	1	0	0	1
187	Yr-1 Q-4	1	1	1	0	1	3	0	3	1	1	1	0	0	1
188	Yr-2 Q-1	1	0	1	0	0	3	0	3	1	1	0	0	0	1
189	Yr-2 Q-2	0	0	0	0	1	3	0	2	1	1	0	1	1	1
190	Yr-2 Q-3	1	1	0	0	1	3	0	3	1	1	0	0	0	1
191	Yr-2 Q-4	0	1	1	0	1	3	0	4	1	1	1	0	0	1
192	Total	4	5	4	2	7	23	1	20	7	8	4	1	2	8
193		YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
194	Day														
195	1_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
196	1_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
921	8_90	0	0	0	0	0	0	0	0	0	0	0	0	0	0
922	8_91	0	0	0	0	0	0	0	0	0	0	0	0	0	0
923	Total	4	5	4	2	7	23	1	20	7	8	4	1	2	8

Cell	Formula
K2	=ROUNDUP(C2/$S2,0)
Y2	=AVERAGE(T2:X2)
Z2	=SUM(C2:J2)
AA2	=SUM(K2:R2)
AB2	=AA2*S2
AC2	=AB2/Z2
AD2	=IF(T2=U2=V2=W2=X2, "NO", "YES")
AC38	=AVERAGE(AC2:AC36)
B180	=VAR(B195:B922)
B181	=AVERAGE(B195:B922)
B182	=B180/B181
B192	=SUM(B184:B191)
B193	=IF(B923=B192,"YES","NOT!")
B923	=SUM(B195:B922)

Visual Basic Application

```
Private Sub CommandButton1_Click()
'post demand values in "demands" sheet

    Application.ScreenUpdating = False

partcount% = 35   'total B-2 part columns

For clm% = 2 To partcount% + 1

'initialize with 0 demands in each cell

    For i% = 195 To 922
      Cells(i%, clm%) = 0
    Next i%

'allocate 1st quarter demands

    dmd% = Cells(184, clm%)       'read the demand

    For i% = 1 To dmd%
      rw% = (Int(Rnd * (90) + 1)) + 194
      Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

'quarter 2
    dmd% = Cells(185, clm%)       'read the demand

    For i% = 1 To dmd%
      rw% = (Int(Rnd * (90) + 1)) + 285
      Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

'quarter 3
    dmd% = Cells(186, clm%)       'read the demand

    For i% = 1 To dmd%
      rw% = (Int(Rnd * (90) + 1)) + 376
      Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

'quarter 4
    dmd% = Cells(187, clm%)       'read the demand
```

```
    For i% = 1 To dmd%
       rw% = (Int(Rnd * (90) + 1)) + 467
       Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

'quarter 5
    dmd% = Cells(188, clm%)        'read the demand

    For i% = 1 To dmd%
       rw% = (Int(Rnd * (90) + 1)) + 558
       Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

'quarter 6
    dmd% = Cells(189, clm%)        'read the demand

    For i% = 1 To dmd%
       rw% = (Int(Rnd * (90) + 1)) + 649
       Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

'quarter 7
    dmd% = Cells(190, clm%)        'read the demand

    For i% = 1 To dmd%
       rw% = (Int(Rnd * (90) + 1)) + 740
       Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

'quarter 8
    dmd% = Cells(191, clm%)        'read the demand

    For i% = 1 To dmd%
       rw% = (Int(Rnd * (90) + 1)) + 831
       Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%

    Application.ScreenUpdating = True

Next clm%

End Sub
```

Appendix F. JMP Screen Shots for New Regression Function Method

	VTMR	Mean	Formula VTMR=1+am^b	Fitted Formula VTMR=1+am^b
1	0.99587345	0.625	1.00995311	1.00000465
2	0.99449794	8.125	1.0102117	1.00021451
3	0.99587345	6.375	1.01018696	1.00014932
4	0.99449794	0.875	1.00998666	1.00000769
5	0.99724897	7.125	1.0101983	1.00017631
6	0.99724897	6.125	1.01018289	1.00014066
7	0.99587345	7.875	1.01020851	1.00020473
8	0.98899587	12.375	1.01025476	1.00040209
9	0.99587345	9.5	1.01022768	1.00027093
10	0.99862448	3.875	1.01013638	1.000071
11	0.99037139	3.375	1.01012238	1.00005776
12	0.99449794	1	1.01	1.00000939
13	0.99037139	15.25	1.0102762	1.00054931
14	0.99037139	11.875	1.01025053	1.00037807
15	1.02767538	16.875	1.01028661	1.00063898
16	0.99862448	2.5	1.01009205	1.0000369
17	0.99174691	10.5	1.01023792	1.0003146
18	1.00456911	36.75	1.01036699	1.00204307
19	1	3.25	1.01011856	1.0000546
20	0.99174691	8.25	1.01021326	1.00021946
21	0.99449794	8.75	1.01021927	1.00023961
22	0.98899587	13	1.01025981	1.0004328
23	0.9738652	32.625	1.01035465	1.00171026
24	0.99174691	2.25	1.01008142	1.00003153
25	0.99037139	2.625	1.01009698	1.00003969
26	0.99587345	1	1.01	1.00000939
27	0.99037139	14.25	1.01026924	1.0004964
28	0.99587345	0.875	1.00998666	1.00000769
29	1	3.125	1.0101146	1.00005149
30	0.99724897	0.625	1.00995311	1.00000465
31	0.99724897	6.375	1.01018696	1.00014932
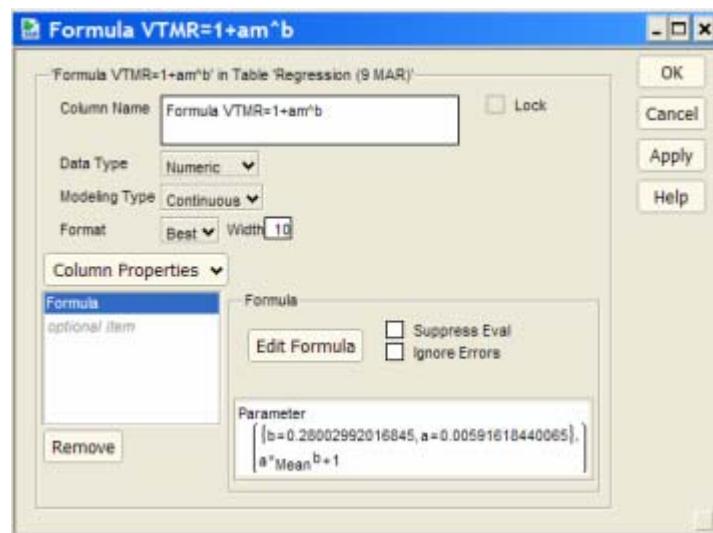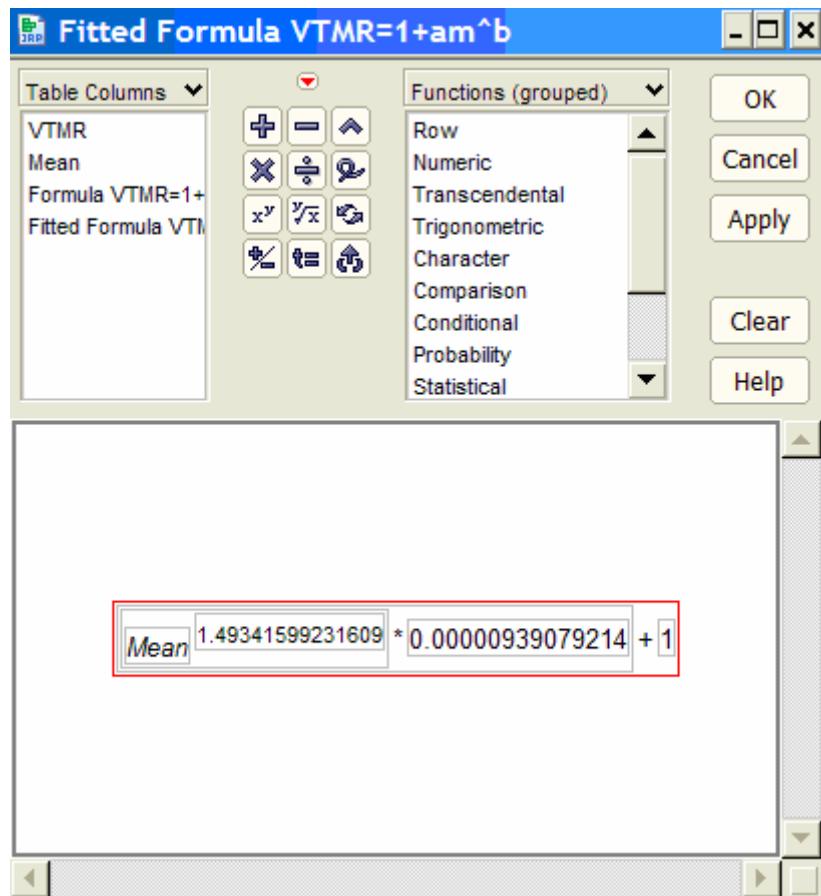
Appendix G. Spreadsheet to Facilitate Baseline VTMR Calculations

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	SGM	Total Demands 2000-2002	Total Flying Hours 2000-2002	Demands /Fly Hour	Flying Hours / Day	DDR	NRTS	NRTS %	BRC	OST	P_B	Baseline VTMR	Floored Baseline VTMR	Capped & Floored Baseline VTMR	Values Only Baseline VTMR
2	005836015	10	4438	0.002253	30	0.067598	100	1	8	12	12	2.64096	2.64096	2.64096	2.64096
3	005956890	87	4438	0.019603	30	0.588103	81	0.81	12	11	10.25087	2.502923	2.502923	2.502923	2.502923
36	014543400	123	1997	0.061592	30	1.847772	54	0.54	16	17	22.7796	3.285602	3.285602	3.285602	3.285602
37	011904934	65	5196	0.01251	20.29	0.25382	100	1	6	12	12	2.64096	2.64096	2.64096	2.64096
38	012013256	26	181	0.143646	20.29	2.914586	0	0	5	8	14.57293	2.821691	2.821691	2.821691	2.821691
203	997714157	8	181	0.044199	20.29	0.896796	100	1	4	8	8	2.300162	2.300162	2.300162	2.300162
204	011448068	5	10374	0.000482	30.89	0.014888	100	1	4	6	6	2.085381	2.085381	2.085381	2.085381
205	012247827	998	5236	0.190604	30.89	5.887743	20	0.2	5	19	27.35097	3.496872	3.496872	3.496872	3.496872
266	014689407	25	212	0.117925	30.89	3.642689	33	0.33	3	9	10.2918	2.506324	2.506324	2.506324	2.506324

Cell	Formula
D2	=B2/C2
F2	=D2*E2
H2	=G2/100
K2	=F2*(1-H2)*I2+(H2*J2)
L2	=1.132477*(K2^0.3407513)
M2	=IF(L2<1.01,1.01,L2)
N2	=IF(M2>5,5,M2)

Column E	
Airframe	Office Symbol of Source
A-10A	A10SS/LG
B-2A	B2SG/VA
F-15E	USAF F15SG/VA

Column	Source
G	D200A
I	D200A
J	D200A
O	Column N (Copy, Paste Special, Values)

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Appendix H. ASM Template with Baseline VTMRs for the A-10

	rtype	nsn	cost	iqpa	qpanha	fap	pltt	itasse	fil1	nhansn	ibudcode	neglv	fil2	maintcon
1	rtype	nsn	cost	iqpa	qpanha	fap	pltt	itasse	fil1	nhansn	ibudcode	neglv	fil2	maintcon
2	LRU	005836015	3061.26	2	2	1	11	0		A10A	1	0		RR
3	LRU	005956890	5297	2	2	1	2	0		A10A	1	0		RRR
4	LRU	010035568	3984.2	1	1	1	6	0		A10A	1	0		RR
5	LRU	010035583	1992.7	2	2	1	17	0		A10A	1	0		RRR
6	LRU	010053017	3189.5	1	1	1	13	0		A10A	1	0		RRR
7	LRU	010105956	4404.23	6	6	1	13	0		A10A	1	0		RRR
8	LRU	010112878	3912.1	2	2	1	13	0		A10A	1	0		RRR
9	LRU	010131962	12000	3	3	1	11	0		A10A	1	0		RRR
10	LRU	010164850	3045	2	2	1	10	0		A10A	1	0		RRR
11	LRU	010222634	3078	2	2	1	1	0		A10A	1	0		RRR
12	LRU	010227802	1076.38	1	1	1	11	0		A10A	1	0		RRR
13	LRU	010248733	779.5	1	1	1	11	0		A10A	1	0		RR
14	LRU	010271206	3753.02	6	6	1	11	0		A10A	1	0		RRR
15	LRU	010307950	12150	1	1	1	4	0		A10A	1	0		RRR
16	LRU	010344516	3444.17	1	1	1	11	0		A10A	1	0		RRR
17	LRU	010348949	2615.1	1	1	1	5	0		A10A	1	0		RRR
18	LRU	010348993	12150	1	1	1	3	0		A10A	1	0		RR
19	LRU	010351386	2760.26	3	3	1	27	0		A10A	1	0		RRR
20	LRU	010352338	4774	2	2	1	11	0		A10A	1	0		RRR
21	LRU	010362944	12150	1	1	1	12	0		A10A	1	0		RR
22	LRU	010370329	7967	1	1	1	17	0		A10A	1	0		RRR
23	LRU	010418543	12150	1	1	1	6	0		A10A	1	0		RR
24	LRU	010436531	12500	1	1	1	10	0		A10A	1	0		RRR
25	LRU	010472304	6639	1	1	1	11	0		A10A	1	0		RRR
26	LRU	010533195	4720.24	1	1	1	13	0		A10A	1	0		RRR
27	LRU	010723536	996.05	2	2	1	11	0		A10A	1	0		RR
28	LRU	012039792	1670	2	2	1	11	0		A10A	1	0		RRR
29	LRU	012778984	1862.76	1	1	1	11	0		A10A	1	0		RRR
30	LRU	012940043	21275	1	1	1	13	0		A10A	1	0		RRR
31	LRU	013065593	2449.46	1	1	1	11	0		A10A	1	0		RRR

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	itembuy	fil3	cannflag	fil4	nopflag	earlypct	ibrtp	ibrtw	iostp	iostw	idrtp	idrtw	toimdrp	toimdrw
2	0		N		MIN	1	8	8	12	12	33	33	0.000101	0.000101
3	0		N		MIN	1	12	12	11	11	48	48	0.000274	0.000274
4	0		N		MIN	1	4	4	14	14	41	41	0.000352	0.000352
5	0		N		MIN	1	4	4	9	9	45	45	0.000025	0.000025
6	0		N		MIN	1	4	4	13	13	32	32	0.00051	0.00051
7	0		N		MIN	1	8	8	9	9	94	94	0.000078	0.000078
8	0		N		MIN	1	1	1	13	13	46	46	0.000233	0.000233
9	0		N		MIN	1	30	30	17	17	31	31	0.000168	0.000168
10	0		N		MIN	1	1	1	15	15	12	12	0.000252	0.000252
11	0		N		MIN	1	10	10	12	12	38	38	0.000157	0.000157
12	0		N		MIN	1	5	5	11	11	32	32	0.000251	0.000251
13	0		N		MIN	1	4	4	12	12	32	32	0.000045	0.000045
14	0		N		MIN	1	15	15	22	22	16	16	0.000039	0.000039
15	0		N		MIN	1	3	3	13	13	51	51	0.000529	0.000529
16	0		N		MIN	1	2	2	13	13	36	36	0.00104	0.00104
17	0		N		MIN	1	4	4	9	9	33	33	0.000113	0.000113
18	0		N		MIN	1	11	11	14	14	49	49	0.000472	0.000472
19	0		N		MIN	1	2	2	13	13	46	46	0.000493	0.000493
20	0		N		MIN	1	2	2	14	14	68	68	0.000308	0.000308
21	0		N		MIN	1	7	7	13	13	73	73	0.000497	0.000497
22	0		N		MIN	1	5	5	13	13	69	69	0.000536	0.000536
23	0		N		MIN	1	7	7	13	13	49	49	0.000612	0.000612
24	0		N		MIN	1	4	4	14	14	54	54	0.002023	0.002023
25	0		N		MIN	1	2	2	14	14	34	34	0.000126	0.000126
26	0		N		MIN	1	1	1	11	11	57	57	0.000264	0.000264
27	0		N		MIN	1	4	4	12	12	41	41	0.00001	0.00001
28	0		N		MIN	1	4	4	9	9	26	26	0.000472	0.000472
29	0		N		MIN	1	4	4	7	7	116	116	0.000048	0.000048
30	0		N		MIN	1	4	4	15	15	62	62	0.002405	0.002405
31	0		N		MIN	1	4	4	8	8	82	82	0.000036	0.000036
32	0		N		MIN	1	6	6	10	10	31	31	0.000306	0.000306

	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1	bnrtsp	bnrtsw	conpctp	conpctw	class	itemname	iafid	usnsn	manager	rmssbuy	wpnsys	sivug	vmr_num	comasset
2	0	0	0	0	R	PUMP,FUEL,				0		0	2.64	0
3	0	0	0	0	R	ACTUATOR,E				0		0	2.5	0
4	0	0	0	0	R	PUMP ASSEM				0		0	2.78	0
5	1	1	1	1	R	REGULATOR,				0		0	2.18	0
6	0	0	0	0	R	VALVE,SOLE				0		0	2.68	0
7	0	0	0	0	R	ACTUATOR,E				0		0	2.37	0
8	0	0	0	0	R	VALVE,REGU				0		0	2.61	0
9	0	0	0	0	R	VALVE,REGU				0		0	2.97	0
10	0	0	0	0	R	VALVE ASSE				0		0	2.77	0
11	0	0	0	0	R	PUMP,SUBME				0		0	2.53	0
12	0	0	0	0	R	SWITCH,PRE				0		0	2.5	0
13	0	0	0	0	R	CONTROL PA				0		0	2.64	0
14	0	0	0	0	R	BODY,VALVE				0		0	3.15	0
15	0	0	0	0	R	CONTROL AS				0		0	2.68	0
16	0	0	0	0	R	CONTROL AS				0		0	2.65	0
17	0	0	0	0	R	CONTROL ST				0		0	2.24	0
18	0	0	0	0	R	CONTROL AS				0		0	2.78	0
19	0	0	0	0	R	ACTUATOR,E				0		0	2.67	0
20	0	0	0	0	R	VALVE,REGU				0		0	2.69	0
21	0	0	0	0	R	CONTROL AS				0		0	2.71	0
22	0	0	0	0	R	ACTUATOR,E				0		0	2.69	0
23	0	0	0	0	R	CONTROL AS				0		0	2.71	0
24	0	0	0	0	R	ACTUATOR,E				0		0	2.88	0
25	0	0	0	0	R	VALVE,SOLE				0		0	2.69	0
26	0	0	0	0	R	ACTUATOR,E				0		0	2.52	0
27	0	0	0	0	R	VALVE,FLUI				0		0	2.64	0
28	0	0	0	0	R	INDICATOR,				0		0	2.36	0
29	0	0	0	0	R	CIRCUIT CA				0		0	2.11	0
30	0	0	0	0	R	SLIPWAY,RE				0		0	2.85	0
31	0	0	0	0	R	CIRCUIT CA				0		0	2.02	0

	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC
1	compipe	com_ddr	order_qty	share_p	share_w	code_name	sch_maint	alt_code	weight	volume	fapnha	resource	part_num
2	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
3	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
4	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
5	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
6	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
7	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
8	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
9	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
10	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
11	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
12	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
13	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
14	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
15	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
16	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
17	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
18	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
19	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
20	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
21	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
22	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
23	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
24	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
25	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
26	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
27	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
28	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
29	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
30	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	
31	0	0	0	1	1	COMPUTED	0	0	0	0	0	0	

	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO
1	part_num	descript	alt_name	mttr	repaircost	essential	dem_fac						
2				0	0	1	0						
3				0	0	1	0						
4				0	0	1	0						
5				0	0	1	0						
6				0	0	1	0						
7				0	0	1	0						
8				0	0	1	0						
9				0	0	1	0						
10				0	0	1	0						
11				0	0	1	0						
12				0	0	1	0						
13				0	0	1	0						
14				0	0	1	0						
15				0	0	1	0						
16				0	0	1	0						
17				0	0	1	0						
18				0	0	1	0						
19				0	0	1	0						
20				0	0	1	0						
21				0	0	1	0						
22				0	0	1	0						
23				0	0	1	0						
24				0	0	1	0						
25				0	0	1	0						
26				0	0	1	0						
27				0	0	1	0						
28				0	0	1	0						
29				0	0	1	0						
30				0	0	1	0						
31				0	0	1	0						

Appendix I. Two of Five Files Needed to Run ASM

a10a_d.xls

	A	B	C	D	E	F	G	H	DA	DB	DC	DD	DE
1	periodtype	run_begin	run_end	fh_ac	begin_yr	schedunits	scen_day00	scen_day01	scen_day98	scen_day99			
2	Month	1	12	1.11111	2000	FLEET	0	27	0	0			
3													
4													

A10A_M.DBF

```
1.00          0              -1TOTAL         1      30.00    2.22222    0.50000    10.000        27
```
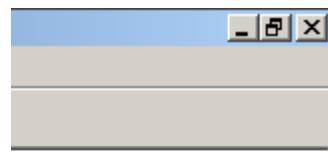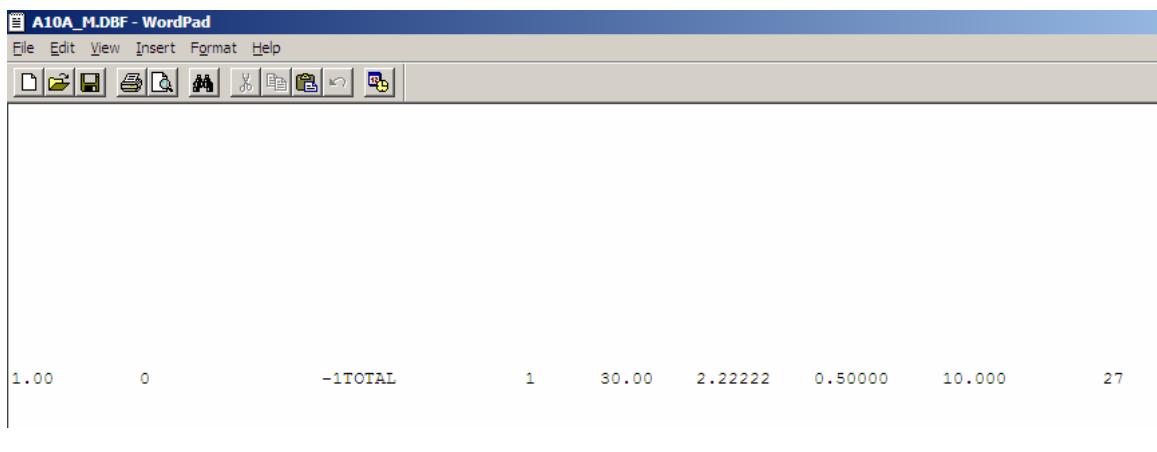
```
1.35          1.00☐
```

Appendix J. ASM Output Screen Shots for A-10 Budget Target

Performance Report

All Runs	Summary Performance for Run	Budget Codes for Run	Base Sets for Run

System: A10A   Run Date: 03/13/2006   Run#   44

Run Description: RUN #44: BASELINE - 95%: 58   Kit#   58

Kit Name & Description: BASELINE A-10   95%

Total Buy Cost: $ 199,242

Total Initial Assets: $ 0

Browse All Item Data

Daily Performance	Analysis Day 1 - 0	Analysis Day 2 - 0
Availability:	95.14%	0.00%
Expected (achieved) NMCS:	1.312	0.000
Achieved Confidence of NMCS Target:	74.65%	0.00%
Expected Back Orders:		0.00
Buy Cost Breakout:	$ 199,242	$ 0
NMCS Input Target:	1.35	0.01

Print Summary - All Runs	Close	Print This Performance

Appendix K. ASM Input Screen Shots for Hill-Stevens, A-10

Baseline Kit - View \ Edit Parameters

Parameters	Scenario	Advanced Parameters	Delivery

Kit Name: H-S   A-10   Description: BUDGET
Kit ID Number: 61   System: A10A   Date: 03/13/2006

VIEW

Analysis Year: 2000   Asset Projection: For Replenishment: ▼   Coverage Period: 1.00

1st Analysis Day Information   Fleet Size 1 27
1st Analysis Day: 0
1st NMCS Target: 0.27 ──┐
1st Availability: 99.00 % ──┘─ OR
1ST Confidence: 0 % ──┐
1st Budget: 199,242 ──┘─ OR
Cannibalization: LRUs=No : SRUs=No   ▼

2nd Analysis Day Information   Fleet Size 2 27
2nd Analysis Day: *
2nd NMCS Target: 0.01 ──┐
2nd Availability: 99.96 % ──┘─ OR
2nd Confidence: 0 % ──┐
2nd Budget: 0 ──┘─ OR
Cannibalization: LRUs=No : SRUs=Yes   ▼

Comment: [   ]   Close Comments

Item Data

| ◄◄ ◄ | Find Kit | ► ►► | Modify | Undo | Save | Print | Delete | Close |

Appendix L. ASM VTMR = 1.01 F-15E Export File

	A Team&Desc	B Buy Total	C Buy Cost	D NSN	E Tot Pipe 1	F Tot Pipe 2	G Demand 1	H Resupply Days
2	ACTUATOR,E	1	8391.09	011448068	0.01	0	0.00358	3
3	CONTROL-IN	3	168882	012247827	0.65	0	0.12974	5
4	CONTROL AS	1	2377.45	012257244	0	0	0.00068	0
5	F15E NLG W	6	15666	012257451	1.1	0	0.21926	5
6	ACTUATOR,E	2	22737.52	012283821	0.06	0	0.01912	3
7	ACTUATOR,E	1	19100	012283822	0.02	0	0.00754	3
8	CONTROL,GE	4	55403.68	012305147	0.77	0	0.07692	10
9	DISPLAY UN	4	384916	012308578	1.16	0	0.2313	5
10	PYLON,AIRC	1	117343	012314665	0.04	0	0.01044	4
11	GENERATOR,	3	65130	012345860	0.41	0	0.08266	5
12	CONVERTER,	2	188000	012368438	0.37	0	0.07318	5
13	ACTUATOR,E	1	16650	012375871	0.04	0	0.01022	4
14	POWER SUPP	1	8190	012390390	0.01	0	0.00176	6
15	REMOTE REA	1	185690	012400136	0.11	0	0.02746	4
16	BLANKER,IN	1	50353.57	012404455	0.02	0	0.00398	5
51	VALVE,BUTT	5	42626	014126652	0.97	0	0.16193	6
52	COMPUTER,A	4	131637.28	014328459	0.82	0	0.07444	11
53	CONVERTER,	1	188937.45	014367588	0.08	0	0.02731	3
54	PROCESSOR,	2	149990	014445142	0.25	0	0.08405	3
55	COMPUTER,F	1	220802	014449008	0.22	0	0.11229	2
56	SERVOMECHA	1	475563	014460599	0.08	0	0.02085	4
57	GEARBOX,AC	1	85085	014566510	0.09	0	0.03086	3
58	GEARBOX,AC	1	78133	014567119	0.12	0	0.03108	4
59	CONVERTER,	2	460651.38	014590687	0.28	0	0.07111	4
60	F15E MLG W	11	100078	014632311	3.82	0	0.63708	6
61	AMPLIFIER,	1	448528	014686073	0.24	0	0.04769	5
62	CONTROL-OS	0	0	014689407	0.15	0	0.04837	3
63	Total	105	$7,148,129.62					

Cell	Formula
H2-H62	=E2/G2
B63	=SUM(B2:B62))
C63	=SUM(C2:C62)

Appendix M. Excel Simulation Layout and VBA

	A	B	C	D	E	F	G
1							
2	SGM	NHA	1st Qtr 2003	2nd Qtr 2003	3rd Qtr 2003	4th Qtr 2003	
3	005836015	A010A	0	2	0	2	
4	005956890	A010A	13	12	11	13	
5	010035568	A010A	1	4	4	9	
6	010035583	A010A	0	0	0	1	
32	013065593	A010A	1	2	0	0	
33	013959929	A010A	4	4	5	4	
34	013977533	A010A	29	26	28	21	
35	014543400	A010A	8	6	7	6	
36	011904934	B002A	1	1	0	0	
37	012013256	B002A	0	3	5	0	
38	012572448	B002A	0	0	0	1	
39	012572449	B002A	1	0	2	0	
40	012614530	B002A	1	1	1	2	
41	012622626	B002A	4	1	4	0	
169	014674875	B002A	0	0	0	2	
170	993960449	B002A	3	2	0	0	
171	997714157	B002A	0	0	1	0	
172	011448068	F015E	0	0	2	1	
173	012247827	F015E	70	78	54	92	
174	012257244	F015E	2	1	0	0	
175	012257451	F015E	105	133	158	125	
176	012283821	F015E	1	3	3	5	
177	012283822	F015E	5	4	1	6	
227	014566510	F015E	18	16	15	24	
228	014567119	F015E	13	19	16	15	
229	014590687	F015E	24	19	22	24	
230	014632311	F015E	310	305	382	311	
231	014686073	F015E	2	1	0	3	
232	014689407	F015E	0	9	1	5	
233							

Master Demand Data / Data / Demands / Pipeline Quantities / Backorders + AA /

	A	B	C	D	E	F	G	H	I	J	K	L	EA	EB	EC	ED	EE	EF	EG	EH
1	SGM B-2A	011904934	012013256	012572448	012572449	012614530	012622626	012622629	012625532	012625534	012625562	012625633	014645559	014647854	014648201	014650736	014674875	993960449	997714157	
2	Spares	4	13	3	3	3	4	19	3	2	3	10	2	1	0	2	1	2	1	
3	Resupply Days	6	5	3	3	1	4	4	4	5	3	8	30	4	3	30	3	3	3	
4	1st Qtrs' Demand at Base	1	0	0	1	1	4	0	0	0	0	1	4	0	4	0	0	3	0	
5	2nd Qtrs' Demand at Base	1	3	0	0	1	1	3	0	0	1	1	1	1	1	0	0	2	0	
6	3rd Qtrs' Demand at Base	0	5	0	2	1	4	14	1	0	1	0	0	1	1	1	0	0	1	
7	4th Qtrs' Demand at Base	0	0	1	0	2	0	10	0	1	1	1	1	0	0	0	2	0	0	
8	Annual Demands (formula)	2	8	1	3	5	9	27	1	1	3	3	6	2	6	1	2	5	1	
9	Annual Demands (values)	2	8	1	3	5	9	27	1	1	3	3	6	2	6	1	2	5	1	
10	Annual Demands Rounded	2	8	1	3	5	9	27	1	1	3	3	6	2	6	1	2	5	1	
11	Paste values into row 9?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
12																				
13	Sherbrooke																			
14																				
15																				
16																				
17																				
18																				
19																				
20																				

Master Demand Data \ Data / Demands / Pipeline Quantities / Backorders + AA /

"Data" Worksheet	
Cell	Formula
B8	=SUM(B4:B7)
B10	=ROUNDUP(B8,0)
B11	=IF(B10=B9,"Y","N")

B-2A

VTMR Method: Sherbrooke

Populate Demands

Demands Each Day

SGM Day	011904934	012013256	012572448	012572449	012614530	012622626	012622629	012625532	012625534	012625562	012625633	012625634	012625660	012626373	012627084	012628036	012631583	012636600	012852872	012906822	014648201	014650736	014674875	9939660449	997714157
1																									
12																				1					
13																									
14													2												
29																									
30																						1			
31																									
32																									
33																						1			
34																									
35										1															
36										1															1
332																									
333																					2				
334																									
335			1																						
360																1									
361																									
365																									
Total Allocated Demands	2	8	1	3	5	9	27	1	1	3	3	2	2	4	12	1	6	2	8	3	6	1	2	5	1
Annual Demand	2	8	1	3	5	9	27	1	1	3	3	2	2	4	12	1	6	2	8	3	6	1	2	5	1
Are they equal?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Master Demand Data / Data \ **Demands** / Pipeline Quantities / Backorders + AA /

"Demands" Worksheet	
Cell	**Formula**
B373	=SUM(B7:B371)
B374	=Data!B9
B376	=IF(B373=B374,"Y","N")

B-2A

VTMR Method: Sherbrooke

Daily Pipeline Quantity

Row	SGM / Day	011904934	012013256	012572448	012572449	012614530	012622626	012622629	012625532	012625534	012625562	012625633	012625634	012625660	012626373	012627084	012628036	012631583	012636600	012652872	012906822	012971536	014648201	014650736	014674875	993960449	997714157
7	1																										
18	12																				1						
19	13																				1						
20	14														2						1						
21	15														2						1						
24	18														2												
36	30																							1			
40	34																							1			
41	35											1												1			
42	36											1		1												1	
43	37											1		1												1	
44	38													1												1	
49	43						1							1													
52	46						1																				
339	333																				2						
340	334																				2						
341	335			1																	2						
342	336			1																							
343	337			1																		1					
344	338																	1				1					
345	339																	1				1					
366	360																	1									
367	361																	1									
371	365																										
373	Resupply Days	6	5	3	3	1	4	4	4	5	3	8	3	10	3	5	0	4	3	4	4	5	3	30	3	3	3
374	Total Pipeline Quantity	12	40	3	9	5	36	108	4	5	9	24	6	20	12	60	0	24	6	32	12	25	18	30	6	15	3
375	Is Total Pipeline Quantity > Resupply Days?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Sheet tabs: Data / Demands / **Pipeline Quantities** / Backorders + AA / Cell Formula Tables

"Pipeline Quantities" Worksheet	
Cell	**Formula**
B373	=Data!B3
B374	=SUM(B7:B371)
B375	=IF(B374>=B373,"Y","N")

B-2A

B-2A Fleet: 20

VTMR Method: Sherbrooke

Expected Backorder	0.0082
Aircraft Availability	100.0%

Backorders Each Day

SGM Day	011904934	012013256	012572448	012572449	012614530	012622626	012622629	012625532	012625534	012625562	012625633	012625634	012625660	014648201	014650736	014674875	993960449	997714157
1																		
30														1				
31														1				
32														1				
33														1				
34														1				
35														1				
77														1				
78														1				
79														2				
80														1				
81														1				
82																		
169																		
170														1				
171														1				
172														1				
173																		
332																		
333																1		
334																1		
335																1		
336																		
365																		
Spares	4	13	3	3	3	4	19	3	2	3	10	5	4	0	2	1	2	1
Total Backorder	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	3	0	0
Average Backorder	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0.01	0	0

"Backorders + AA" Worksheet	
Cell	**Formula**
B3	=SUM(B375:AH375)
B4	=EXP(-B3/M1)
B7	=MAX(0,'Pipeline Quantities'!B7-Data!B$2)
B373	=Data!B2
B374	=SUM(B7:B371)
B375	=B374/365

Visual Basic Application

```
Private Sub Populate_Click()
Dim dta(7 To 371) As Integer

partcount% = 136

   'clear old demands
Worksheets("Demands").Range("B7:EG371").Clear
Worksheets("Pipeline Quantities").Range("B7:EG371").Clear

'post demand values in "demands" sheet

Randomize

For clm% = 2 To partcount% + 1

   '1st Qtr
   dmd% = Worksheets("Data").Cells(4, clm%)
   upperbound = 97: lowerbound = 7
   For i% = 1 To dmd%
      rw% = Int((upperbound - lowerbound + 1) * Rnd + lowerbound)
      Cells(rw%, clm%) = Cells(rw%, clm%) + 1
   Next i%

   '2nd Qtr
   dmd% = Worksheets("Data").Cells(5, clm%)
   upperbound = 188: lowerbound = 98
   For i% = 1 To dmd%
      rw% = Int((upperbound - lowerbound + 1) * Rnd + lowerbound)
      Cells(rw%, clm%) = Cells(rw%, clm%) + 1
```

```
    Next i%


    '3rd Qtr
    dmd% = Worksheets("Data").Cells(6, clm%)
    upperbound = 280: lowerbound = 189
    For i% = 1 To dmd%
        rw% = Int((upperbound - lowerbound + 1) * Rnd + lowerbound)
        Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%


    '4th Qtr
    dmd% = Worksheets("Data").Cells(7, clm%)
    upperbound = 371: lowerbound = 281
    For i% = 1 To dmd%
        rw% = Int((upperbound - lowerbound + 1) * Rnd + lowerbound)
        Cells(rw%, clm%) = Cells(rw%, clm%) + 1
    Next i%


Next clm%


'calculate pipeline quantities for "pipeline quantities" sheet


For d% = 2 To partcount% + 1
    res_days% = Worksheets("Data").Cells(3, d%)
    For i% = 7 To 371
        dta(i%) = Cells(i%, d%)
    Next i%


    For i% = 7 To 371
        For c% = 0 To res_days% - 1
```

```
        If (i% + c% < 372) Then

            If (dta(i% + c%) + dta(i%)) > 0 Then Worksheets("Pipeline
Quantities").Cells(i% + c%, d%) = _

                Worksheets("Pipeline Quantities").Cells(i% + c%, d%) + dta(i%)

        End If

    Next c%

  Next i%

Next d%


End Sub
```

Appendix N. Results From Five Runs of Aircraft Availability Simulation

BASE PIPELINE QUANTITY						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	81.7%	80.5%	80.0%	80.9%	80.7%	80.8%
B-2A	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
F-15E	88.7%	88.6%	88.5%	88.3%	88.3%	88.5%
HILL-STEVENS (220 LRUs)						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	83.5%	93.3%	82.8%	82.5%	82.9%	85.0%
B-2A	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
F-15E	82.8%	82.5%	82.9%	82.8%	82.6%	82.7%
VARIATION of HILL-STEVENS (10 1s)						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	80.8%	81.7%	80.3%	81.5%	81.3%	81.1%
B-2A	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
F-15E	92.5%	92.8%	92.7%	92.3%	92.6%	92.6%
HILL-STEVENS (230 LRUs)						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	81.0%	81.3%	81.2%	81.6%	81.3%	81.3%
B-2A	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
F-15E	92.5%	92.1%	92.3%	91.8%	92.5%	92.2%
SHERBROOKE						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	81.6%	81.8%	81.7%	81.9%	81.5%	81.7%
B-2A	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%
F-15E	91.0%	90.8%	90.7%	90.4%	90.9%	90.8%

VARIATION of SHERBROOKE (10 1s)						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	82.2%	81.7%	81.7%	81.4%	80.9%	81.6%
B-2A	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
F-15E	90.9%	91.1%	91.1%	91.3%	91.0%	91.1%
HISTORICAL DATA						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	81.0%	81.0%	80.5%	80.6%	81.8%	81.0%
B-2A	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
F-15E	76.3%	76.3%	76.8%	76.9%	76.0%	76.5%

NEW REGRESSION FUNCTION						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	81.4%	81.5%	80.7%	82.1%	81.8%	81.5%
B-2A	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
F-15E	76.4%	76.3%	76.7%	76.7%	76.9%	76.6%
VTMR=1.00						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	81.1%	81.4%	80.4%	81.6%	81.7%	81.2%
B-2A	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
F-15E	76.7%	76.6%	76.5%	76.2%	76.5%	76.5%
VTMR=1.01						
	Run 1	Run 2	Run 3	Run 4	Run 5	AVERAGE
Airframe	AA	AA	AA	AA	AA	AA
A-10A	81.3%	82.0%	81.0%	81.4%	81.0%	81.3%
B-2A	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
F-15E	76.8%	75.7%	76.5%	76.7%	76.4%	76.4%

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Vita

Captain Lisa J. Mahon, nee Nelson, grew up in Spruce Creek, PA and graduated from Juniata Valley High School in Alexandria, PA. In 1984 she enlisted in the Air Force at the rank of Airman First Class. She spent 3 years and 2 months as a FB-111A crew chief at Pease AFB, NH before transferring to the Michigan Air National Guard at Seymour Johnson AFB, NC under the Palace Chase Program. While stationed at Seymour Johnson AFB, she served as the alert launch crew chief for both the F-4D and F-16C/D aircraft. In 1991 she graduated from Atlantic Christian College in Wilson, NC with a Bachelor of Science Degree in Accounting. In 1993, she transferred to Selfridge Air National Guard Base (ANGB) in Mount Clemens, MI. This permanent change of station brought a career change. In her first four years at Selfridge AFB, Lisa served as an Account Control Technician and Military Pay Supervisor rising to the rank of Master Sergeant.   She then graduated from the Academy of Military Science (AMS) at McGhee-Tyson ANGB, Alcoa, TN where she earned her commission as a Second Lieutenant in 1997. She returned to Selfridge ANGB and assumed the position of Installation Deployment Officer (IDO) in Wing Plans. Next, this now Logistics Plans Officer, soon to be a Logistics Readiness Officer, reentered the active duty Air Force in 2002 at Whiteman AFB, MO. Lisa was subsequently assigned to the Air Force Institute of Technology (AFIT), Wright-Patterson AFB, OH in August 2004, and will move on to the Tanker Airlift Control Center, Air Mobility Command, Scott AFB, IL upon graduation in March of 2006.

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14. ABSTRACT
     In an effort to improve aircraft availability, this research compared the efficiency of ten methods of determining variance-to-mean ratios (VTMRs, VMRs, V/Ms) for repairable, spare aircraft parts known as reparables. These methods are base pipeline quantity, Hill-Stevens (220 LRUs), a variation of Hill-Stevens (10 1s), Hill-Stevens (230 LRUs), the Sherbrooke, a variation of Sherbrooke (10 1s), historical data, a new regression function, variance-to-mean ratio equals 1.00 or variance-to-mean ratio equals 1.01. Using VTMRs derived from quarterly organizational intermediate maintenance (OIM) demands for line-replaceable units (LRUs) from the D200A Secondary Item Requirement System (SIRS) databases in aircraft sustainability model scenarios and Excel spreadsheet simulation, this research concluded the VTMRs have an impact on aircraft availability and the cost of inventory.

15. SUBJECT TERMS
Reparables, Spare Aircraft Parts, Stockage Level, Variance-To-Mean Ratio (VTMR, VMR, V/M), Line-Replaceable Unit (LRU), Aircraft Availability, Aircraft Sustainability Model (ASM)

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